# Demand for cooking fuels in a developing country To what extent do taste and preferences matter?

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## To what extent do taste and preferences matter?

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**Abstract**

Overreliance on biomass energy, such as firewood and charcoal, for cooking in developing countries has contributed to high rates of deforestation and resulted in substantial indoor pollution which has negatively impacted the health of many individuals. However, the effectiveness of public policies aimed at encouraging households to switch to cleaner fuels, such as liquefied petroleum gas (LPG) and kerosene, hinges on the extent to which they are mentally committed to specific fuels. Using data on four cooking fuels (charcoal, firewood, LPG, and kerosene) from the Ghana living standards survey, we found strong evidence that the most preferred fuel is LPG, followed by charcoal, with kerosene the least preferred. In addition, with the exception of kerosene that has price-elastic demand, the price elasticities of demand for the fuel types examined are inelastic. This finding suggests the so-called *fuel-ladder* is not robust.

***Keywords*** Demand for fuel Taste and preferences Ghana

***JEL Classification*** Q41 Q48 Q23 D13

# 1 Introduction

In developing countries, besides expanding agricultural land use and road expansion, the use of firewood and charcoal as cooking fuels has contributed significantly to increasing deforestation and carbon emissions (Geist and Lambin, 2002). It has been estimated that more than 15 million hectares of tropical forests are cleared annually in order to provide for small-scale agriculture or for use as fuel wood for heating and cooking (Cvijetiæ, et al., 2004). There is consensus in the forestry literature that the current level of biomass consumption in many developing countries is threatening the long-term sustainability of natural forests (see, e.g., Bhattacharya and Abdul Salam, 2002; Zein-Elabdin, 1997; Ouedraogo, 2006). Patterns of use of this biomass energy are dynamic, as it responds to factors such as changes in prices and access to sources of other fuel types. Although forest degradation is of global concern, local users of biomass energy generally do not fully internalize forest loss externalities. In many developing countries, including Ghana, in addition to firewood and charcoal, households commonly use kerosene and liquefied petroleum gas (LPG) as cooking fuels, which are more efficient and have less negative environmental and health impacts (Kumar and

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Viswanathan, 2007). If demand for cooking fuel in Ghana is a derived demand,[1] then a household will be indifferent between the effective energy content (i.e., combustion efficiency of energy in kilojoules) of any two types of fuel if the prices of the two fuels are equal. Indeed, the effectiveness of inter-fuel substitution policies aimed at mitigating the negative impacts of biomass energy in developing countries hinges on whether or not households have derived demand for effective energy contents of cooking fuels, and the extent to which they are mentally committed or stacked to specific fuel types (see, e.g., Ouedraogo, 2006).

In Ghana and other developing countries, biomass remains the dominant source of energy for cooking and many other heat applications. Wood fuels, in the form of forest wood, charcoal and wood processing residues, are the most dominant biomass forms of household energy. It has been estimated that most of the 70% of the Ghanaian population residing in rural areas heavily depend on wood fuel for cooking and heating. Additionally, approximately 70% of the total national energy consumption comes from biomass in either direct or processed form (KITE, 1999). Currently, each person uses around 640 kg of wood fuel per annum. Although wood as biomass is often considered a renewable energy source, forest growth in Ghana is less than half of wood fuel demand making wood fuel an unsustainable energy option. Moreover, in Ghana only 975,000 ha of the forest reserve and off-reserve area remains (Mann, et al., 2010).

The pervasiveness of firewood in Ghana is perceived to follow from both its widespread availability and relatively low price. Charcoal is commonly used for household cooking and heating in Ghana. While the role of charcoal as a cooking fuel in developing countries is typically small, it is often widely used in urban and rural areas. Charcoal is more desirable for household use than firewood as it has higher energy content and is simpler to transport. Although it has some advantages over firewood, in comparison to clean cooking fuels, it pollutes more, for example, than LPG. Moreover, the process of producing charcoal is tremendously inefficient, resource intensive, and emits high levels of carbon.

In contrast, kerosene and LPG are commonly used liquid and gaseous modern cooking fuels, respectively. They have a high energy density, high combustion efficiency, and high heat-transfer efficiency with sufficient heat control characteristics indicating these modern fuels provide higher quality services. Kerosene is used extensively in the urban centers for cooking, though its level of urban use varies from one urban center to another (Boadi and Kuitunen, 2006). LPG, which is a mixture of propane and butane, is considered clean because it can be burned very efficiently and emits few pollutants. It is non-toxic, and the specialized stove required for its combustion is simple and easy to use (Bailis, 2004). Its use as a cooking fuel in Ghana varies significantly across the country and from one urban center to another. In some situations, its use is constrained by availability.

Biomass (firewood and charcoal) and petroleum products (kerosene and LPG) all have negative environmental impacts due to emission of particulates at the household and neighborhood levels, depending upon the type of fuel used. If the use of cooking fuel energy is not managed properly, especially charcoal and firewood, the environment and human health can be harmed in many ways. The extraction, transportation, processing, and use of cooking fuels have detrimental effects at all physical scales. Given the dominance of biomass fuel combustion in today's energy system, many problems manifest themselves through emissions into the atmosphere and different forms of air pollution.

Indoor air pollution remains a noteworthy global health menace that needs to be addressed. The literature indicates ambient air pollution levels and personal exposure levels from cooking with traditional fuels are severely high (Duflo, et al, 2008). Cooking with traditional solid fuels on open flames or traditional cooking stoves may result in exposure to extremely damaging toxic pollutants. Moreover, incomplete combustion leads to the release of small particles and other constituents that

[1] Derived demand denotes a situation where the demand for a commodity occurs as a result of demand for another, i.e., the former is a part of production of the second. For example, demand for the effective kilojoules content of a particular fuel type leads to derived demand for that fuel type.

have been shown to be damaging to human health in the household environment (Bhattacharya and Abdul Salam, 2002; Kilabuko et al, 2007; Miah et al., 2009). Yet, too little is known to distinguish any differences in health effects of smoke from different kinds of biomass (Smith et al., 2000). The use of charcoal, a relatively clean-burning fuel, is expected to increase in some developing countries, especially in urban Africa, while the use of household wood fuel and other solid biomass is slowly decreasing. However, charcoal fuel can pose other kinds of health risks and have negative impacts on forest. In Ghana (and Kenya), studies have revealed that a common illness caused by indoor air pollution is acute lower respiratory infection in children (ALRI) and obstructive lung diseases in adults (Ezzati et al., 2000). Further, it is estimated that there are nearly 2.44 million deaths attributable to biomass indoor particle air pollution in developing countries. These may be due to the improper ventilation and incomplete combustion of biomass and other fuels used to meet residential cooking needs.

Inter-fuel substitution is ubiquitous at the household level in developing countries. The substitution between charcoal and firewood is common, especially in rural areas, while LPG is generally substituted for biomass fuels in urban households. However, it has been found that some households stack to biomass fuels. As noted by Davis (1998) even with high availability of modern fuels such as LPG and Kerosene, it is rare that the use of biomass fuels can be completely substituted. In addition, WEC (1999) found that in a town in Sierra Leone two-thirds of the families are stacked to firewood and will not switch to other fuels due to the ease which the wood stove offers in preparation of a staple within the region. Furthermore, the introduction of ethanol gel in South Africa in 2004 received low patronage as many users quickly became disappointed at the low quality of the gel which did not make it burn as hot as paraffin and uncompetitive prices of the gel and stove (FoodprocessingAfrica, 2009)[2]. On the other hand several field studies on ethanol gel conducted in Ethiopia demonstrate the fuel is a viable option as a replacement for paraffin if the price could be made competitive (Energy Lists, 2006)[3].

In Ghana, government policies, including subsidies, aim at promoting widespread use of LPG in households to reduce the pressure on forests and indoor pollution (Karakezi, 1989; UNDP, 2004). The proportion of households using clean cooking fuels has increased in response to policies over the years (i.e., from 4% in 1998 to 9.5% in 2006), but the rate of increase has been very slow and biomass fuels still dominate. If cooking fuels have derived demand, then subsidizing a particular fuel relative to others could significantly reduce the use of the other fuels. Conversely, if households have strong preferences for or are mentally committed to the use of specific fuels, then the optimum subsidy must be high enough to facilitate the switch to the subsidized fuel. The strand of literature that addresses this vital problem is limited.

In this paper, we provide a formal illustration to explain the notion that the demand for energy (i.e., the kilojoules content of the various energy types) may not be a derived demand and that households may map taste of say cooked food to fuel types used to cook it, or may simply have preferences for specific types of fuel. We used data on four fuel types (firewood, charcoal, kerosene, and LPG) from Ghana to empirically validate the theoretical construct. We found strong evidence that households lock into specific fuel types. Specifically, the most preferred fuel is LPG, followed by charcoal. Surprisingly, kerosene is the least preferred fuel, implying the so-called *fuel ladder* is not robust. Thus, households do not progress from the use of biomass energy to kerosene and ultimately to LPG as their living conditions improve. Furthermore, with the exception of kerosene which has price-elastic demand, the price elasticities of demand for the fuel types examined are inelastic.

The remainder of the paper is organized as follows. The model is presented in section 2, followed in section 3 by a description of the data used for the empirical analysis and the presentation of our results. Section 4 provides our concluding remarks and policy recommendations.

[2] The article is entitled "*Blue ethanol gel take-off* " in FoodProcessingAfrica, August 2009 Issue 1.
[3] Bioenergy Lists (2006), Available at http://bioenergylists.org/, as accessed July 2011.

## 2 Theoretical Framework

As noted by Becker (1965), the household can be likened to "a small factory" which combines inputs to produce basic commodities that enters its utility function directly. Suppose a representative household within each cluster of the population *produces* food (i.e., cooked food, $z$) for consumption using kilojoules of energy from firewood ($k$), charcoal ($C$), kerosene ($S$), or LPG ($G$). If the demand for any of the four fuel types is a derived demand (Lancaster, 1966), then the food production function could be specified as

$$z_i = f\left(k + \alpha^s k + \alpha^G k + \alpha^F k\right) = f\left(\sigma k\right), with\ f_k > 0\ and\ f_{kk} < 0 \tag{1}$$

where $f$ is a functional notation, $k$ is the combustion efficiency of kilojoules of a unit of firewood (which is used as the numeraire), $\alpha^S$ is the ratio of combustion efficiency of kilojoules of firewood to that of kerosene and so on, and $\sigma = (1 + \alpha^s + \alpha^G + \alpha^F)$. In the literature, it has been estimated that the average combustion efficiency of the four types of fuel ( firewood, charcoal, kerosene, and LPG) are 15%, 25%, 45%, and 55%, respectively (Mukunda et al., 1988; UNDP/ESMAP, 2003). If the representative agent consumes cooked food and a composite commodity ($x$), then her general utility function is written as

$$u_i = u(z_i, x_i) = u_i(f_i(\sigma k), x_i), with u_x > 0, u_z > 0 \tag{2}$$

We assume the representative agent already has the complementary technologies (stoves) for all of the fuel types; hence there is no switching cost. On the other hand, if there is a switching cost, which is a onetime cost, it will lower the income/budget of the representative agent and consequently lower her demand for fuel. Suppose the representative agent has some fixed income ($B$) that can be spent on fuel and the composite commodity[4]. Her budget constraint could be expressed as

$$(w^k + \alpha^s w^S + \alpha^G w^G + w^F \alpha^F)k + x_i \leq B, \tag{3}$$

where, e.g., $w^F$ is the (relative) price per unit of firewood, and the price per unit of the composite good is normalized to 1. The corresponding Langrangean function is

$$\ell = u(f_i(.), x_i) + \lambda(B - (w^k + \alpha^s w^S + \alpha^G w^G + w^F \alpha^F)k - x_i). \tag{4}$$

The first-order conditions of equation (4) with respect to $k$ and $x$ are given by equations (5) and (6) respectively:

$$\frac{\partial \ell}{\partial k} = \frac{\partial u(f_i(.), x_i)}{\partial f}\frac{\partial f}{\partial k} - \lambda(w^k + \alpha^s w^S + \alpha^G w^G + w^F \alpha^F) = 0, \tag{5}$$

$$\frac{\partial \ell}{\partial x} = \frac{\partial u(f_i(.), x_i)}{\partial x} - \lambda = 0 \Leftrightarrow \frac{\partial u(f_i(.), x_i)}{\partial x} = \lambda \quad . \tag{6}$$

Combining equations (5) and (6) yields

$$\left(\frac{\partial u(f_i(.), x_i)/\partial f_i(.)}{\partial u(f_i(.), x_i)/\partial x}\right)\left(\frac{\partial f_i(.)}{\partial k}\right) = (w^k + \alpha^s w^S + \alpha^G w^G + w^F \alpha^F). \tag{7}$$

Suppose the relative price of the energy type depends on its kilojoules content. Then $(w^k + \alpha^s w^S + \alpha^G w^G + w^F \alpha^F) = w^k \sigma$, and equation (7) can be re-specified as:

$$(MRS_{z,x})(MP_k) = \sigma w^k \Leftrightarrow MRS_{z,x} = \frac{\sigma w^k}{MP_k} \tag{8}$$

[4] This could be assumed to be the income remaining after acquiring the stoves.

where $MRS_{z,x} = \frac{\partial u(f_i(.),x_i)/\partial f_i(.)}{\partial u(f_i(.),x_i)\partial x}$ is the marginal rate of substituting $z$ for $x$, $MP_k = \partial f_i(.)/\partial f_i(.)/\partial k$ is the marginal product of charcoal, and $\sigma w^k/MP_k$ is the marginal cost of cooked food relative to the price of charcoal. Therefore, equation (8) stipulates that, in equilibrium, the marginal rate of substitution equals the marginal cost of cooked food relative to the price of kerosene. Now, suppose the taste of food depends on the fuel type $i$ used to cook it (where $i = k, F, s, G$),[5] or households prefer to use specific fuel types to cook. To illustrate the impact of taste on the demand for a particular type of fuel, we use the following specific function: $u(z,x) = z^{\theta}x^{1-\theta}$ and $z = \sigma k$, where $\theta$ captures the preferences between the food cooked with a particular fuel type and the composite good. The corresponding demand function is denoted by

$$k = \frac{B}{w^k}\left(\frac{\theta}{\sigma}\right). \tag{9}$$

Note that $\sigma^{-1}$ and $(\theta/\sigma)$are the relative kilojoules efficiency and relative taste parameter for a fuel type (say firewood, $k$). From equation (9), $\partial k/\partial(\theta_k) > 0$, indicating that, all other things being equal, the household will buy a relatively higher quantity of a particular fuel type if the taste of food cooked by that fuel type is preferred to that of other types of fuel or if the household has specific preferences for a particular fuel. From equation (9), our empirical model is written as

$$\ln(k_j) = \rho + \alpha_0 \ln(B_{jk}) - \alpha_1 \ln(w_{jk}) + \alpha_2 \ln(\theta_{jk}) + \varepsilon_{jk}, \tag{10}$$

where $\rho = \ln\left(\sigma^{-1}\right)$ is the intercept and $j$ is a cluster-specific index. Note that $B_{jk}$ controls for the switching cost. Since $\theta_{jk}$ is fuel type and a household-specific index, we introduce fuel-specific dummies $(D_{jk})$ and some household characteristics $(S_j)$ in a stacked regression model that combines all the data on each of the four fuel types:

$$\ln\left(k_j\right) = \rho + \alpha_0 \ln(B_{jk}) - \alpha_1 \ln(w_{jk}) + \alpha_{21}(D_{jk}) + \alpha_{22}(S_j) + \varepsilon_{jk}, \tag{11}$$

Equation (11) has been estimated and the results are presented in section 4. We hypothesis that if taste and preferences do not matter, then $\alpha_{21} = \alpha_{22} = 0$.

Now, suppose we fail to reject the hypothesis that demand for energy is a derived demand. Assume the household consumes a typical food that can be cooked with different types of fuel (i.e., inputs) which are perfect substitutes in the food production (i.e., cooking) function [as defined in equation 1]. Furthermore, since the taste of food may depend on the type of energy used to cook it, or individuals may prefer to cook with some specific fuel, we consider a particular food cooked with, e.g., firewood and LPG as different commodities. For example, grilled fish may taste different depending on the fuel type used. Since a typical household uses different types of energy, the household may cook a particular food with different energy types, and hence different commodities.

Let $z_i$ be food cooked with energy type $i$, where $i$ represents any two of the four energy types. The corresponding Langrangean function is:

$$\ell = u(z_k, z_g) + \lambda\left(B - w^k k - w^g G\right) \quad . \tag{12}$$

From the first-order conditions with respect to $z_k$ and $z_g$, we have

$$\left(\frac{\partial u(z_k, z_g)/\partial z_k}{\partial u(z_k, z_g)/\partial z_g}\right)\left(\frac{\partial f/\partial k}{\partial f/\partial G}\right) = w^k \quad . \tag{13}$$

If we assume a constant elasticity of substitution utility function and a constant returns to scale production function for each fuel type [e.g., $u(z_k, z_g) = \left(\alpha z_k^{\rho} + (1-\alpha)\, z_g^{\rho}\right)^{1/\rho}$ and $z_k = \sigma k$], we have

$$k = k(B, w^k, w^g), \tag{14}$$

[5]For example, the taste of grilled fish may depend on the fuel type used.

where $\partial k/_{\partial B} > 0$ and $\partial k/_{\partial w^k} < 0$. If the fuel types are substitutes, then $\partial k/_{\partial w^g} > 0$. Our empirical model from equation (15) is specified as

$$\ln k_j = \rho + \alpha_B \ln B_{jk} + \alpha_s S_{jk} - \alpha_k \ln w_{jk} + \alpha_g \ln w_{jg} + \alpha_F \ln w_{jF} + \alpha_c \ln w_{jc} + \varepsilon_{jk}. \quad (15)$$

We have estimated equation 15 and the results are presented in the next section.

# 3 Data Description and Empirical Analysis

The data source used for this work is the Ghana Living Standards Survey Fourth Round (GLSS4) collected by Ghana statistical services between 1998/1999. Although the data are quite old, they are the most credible available in Ghana that have all the relevant variables. Recent studies on fuel policies in Ghana have used the GLSS4 as well (e.g., see Coady et al., 2006; Akpalu and Robinson, 2009). Further, from observations, fuel use patterns have not changed significantly. In total, 65,222 households grouped into 1,208 clusters across the country have been used for our analysis. In addition to fuel type used by each household in each cluster and the price of each fuel, detailed data on household demographics and total expenditures were also collected. The survey classifies the country into three ecological zones: coastal, forest, and savannah.

Table 1 presents the summary statistics of quantity demanded and prices of the variables used in estimating the demand for the fuel types per cluster. The analysis reveals differences between the means and standard deviations of LPG, firewood, and the average prices of all four fuels. The standard deviations for LPG, firewood, and prices of all fuel types are lower than the means, indicating that on the average, there are no significant variations in the variables. In contrast, the mean values are lower than the standard deviation for charcoal and kerosene, implying the variables are relatively widespread around their means. Table 2 shows the demand for cooking fuel per cluster. We have converted all cooking fuel types to kilojoules. The summary statistics depict the means and standard deviations of each variable per cluster. The mean household expenditure, level of education, age, and marital status per cluster are higher than their respective standard deviation. On the other hand, energy usage, prices of all fuel types, and the ecological zones showed some higher values of standard deviation compared to the means. The dummies for ecological zones have been used to account for spatial availability of the different fuel types.

Table 3 reports the regression results of equation (14). The dependent variable is kilojoules per cluster and the explanatory variables are the price of the fuel, average household expenditure per cluster, socioeconomic characteristics, and fuel type dummy to capture taste. As expected, the relationship between prices and the quantity of kilojoules demanded is negative; the relationship is significant at the 1% level with an elasticity coefficient of -0.86 (i.e., fairly inelastic). This finding implies that an increase in the price per kilojoule of fuel would cause the consumption of energy to decrease, but with less than a proportionate increase in price. The average expenditure per cluster is significant at the 1% level and positively related to the dependent variable (i.e., kilojoules of energy). The elasticity coefficient of 0.3 indicates that fuel is a normal good. The average age per cluster is negatively related to the quantity demanded of kilojoules of fuel and significant at the 5% level, suggesting that the clusters with relatively older populations use less cooking fuel. The elasticity coefficient of -0.76 is more than twice that of the average expenditure per cluster.

With respect to our main hypothesis, the coefficients of each of the fuel-specific dummies are highly significant (1% level), indicating there are significant differences among the preferences for the various fuel types. Clearly, demand for cooking fuel is not a derived demand. From the elasticity coefficient, LPG is the most preferred fuel, followed by charcoal and then firewood, with kerosene being the least desired. Although this analysis is based on cross-sectional data, it confirms that households' most preferred energy (i.e., LPG) is the fuel found by most earlier studies to be on the top of the "fuel ladder" (see, e.g., Gundimeda and Kohlin, 2008; Arnold et al., 2003). Our conclusion that kerosene is the least preferred contradicts the finding of Campbell et al. (2003) who found a transition by households from wood to kerosene in urban Zimbabwe. However, our results are consistent with the finding that households do not forgo solid fuels in favor of say liquid, which is thought to be preferable because it burns more cleanly (Masera et al., 2000). Several explanations can be offered for this choice. First, kerosene stoves generate significantly lower power than the traditional wood fire. As a result, it may take a longer period of time to cook with a kerosene stove. Second, kerosene stoves may not support the round-bottom cooking pots used in some households. Third, the kerosene stoves are not robust due to its design. Indeed, they are generally deficient at cooking porage, a staple in many homes with large household.

Finally, the exclusion from the regression of age and proportion of households that are married within the cluster did not affect the elasticity coefficients of the remaining variables in the regression.

Table 4 presents the estimated results of the demand equation for each of the fuel types converted to kilojoules. As expected, the price of each type of fuel has a negative relationship with its quantity demanded, all other things being equal, and the coefficients are statistically different from zero. In addition (except kerosene), the price elasticity of demand for each of the fuel types is inelastic (i.e., less than one). The elasticity coefficient for kerosene is -1.3 (i.e., elastic) and the corresponding value for firewood, which is the lowest, is -0.87. Thus, on the average, households' quantity demanded for kerosene is relatively very sensitive to price changes compared to the three other types of fuel, and quantity demanded for firewood is the least sensitive to price changes. This result provides an explanation for the dominance of biomass energy in Ghana in spite of policies that have been implemented to encourage the use of LPG. Moreover, this finding offer further evidence that in Ghana the demand for fuel is not primarily a derived demand. Mekonnen and Köhlin (2008) and Takama et al. (2009) using a discrete choice models of fuel choice found evidence of fuel-stacking in Ethiopia and suggest that, besides prices of fuel, other socio-economic factors such as preferences and habit could be responsible. It has also been documented in the literature that, even with high availability of modern fuels such as LPG and Kerosene, it is hardly the case that the use of biomass fuels can be completely substituted (see, e.g., Mehlwana and Qase, 1996; Davis, 1998; and WEC, 1999). In contrast, the "butanisation" program in Senegal aimed at encouraging households to switch to LPG through government subsidies achieved a remarkable success of 85 percent patronage in 1995 after 21 years (1974-1995) of implementation (Denton, 2004). However the growth in demand declined when the subsidy was subsequently reduced. The cross-elasticities for charcoal with respect to prices of kerosene and firewood are statistically significant at the 5% and 10% levels, respectively. The elasticity coefficients are positive, indicating households substitute kerosene and firewood for charcoal if the price of either of these two fuel types increases. The elasticity coefficient of kerosene (0.98) is higher than the own-price elasticity of charcoal, suggesting households easily shift to the use of charcoal when the price of kerosene increases. Second, the demand for firewood is not responsive to the change in price of any of the three other types of fuel revealing a strong indication that subsidizing the other types of fuel may not reduce the quantity of firewood used by households. Third, the cross-elasticities of LPG with respect to the prices of kerosene and firewood are significant at 1% and 5% levels, respectively. However, while the sign of the coefficient indicates LPG and kerosene are substitutes (i.e., households substitute kerosene for LPG and vice versa), the sign of LPG and firewood show they are complements. A possible albeit remote explanation for this unexpected result could stem from the fact that occasional shortages of LPG create a natural reduction in its quantity demanded, which in turn causes the demand for firewood (a substitute) to increase, resulting in the increase of the price of firewood. Note that the cross-elasticity coefficient of the price of kerosene is 1.97, which is more than twice that of the own-price elasticity of LPG; hence a tax on kerosene is very likely to result in a drastic increase in the demand for LPG, all other things being equal.

Apart from the household expenditure on firewood, which is not significant, the expenditure on all other energy types was significant at 1% for charcoal, 5% for kerosene, and 5% for LPG. The elasticity coefficient for the expenditure for all three fuel types is inelastic and positive, indicating each fuel is a normal good to the household. Thus, while the demand for firewood does not depend on the income or expenditure level of the household, richer households are likely to use more charcoal.

This is consistent with a study on Ethiopia which found that, as opposed to the energy-ladder hypothesis, firewood is not inferior (Mekonnen and Köhlin, 2008). Concerning the three ecological zones (forest, savannah, and coastal), firewood is used more in the savannah zone than in the other zones, LPG is used more in the costal zones, and kerosene is used less in the coastal zone relative to the others. Charcoal usage is not significantly different across the ecological zones. Consequently, energy policy toward discouraging the use of firewood should concentrate on the savannah zones.

# 4 Conclusion and policy recommendations

Public energy management policies in many developing countries have largely focused on industrial energy consumption and power plants rather than residential energy use (Naidoo and Matlala, 2005). On the other hand, the overreliance by the majority of the population (over 70%) on biomass energy has left in its wake the threat of deforestation and desertification in many parts of the country, as well as negative health impacts from emissions from such energy sources (Ministry of Mines and Energy, 1998). The effectiveness of policies advanced to encourage households to switch to modern and more efficient energy (e.g., LPG and kerosene) depends on whether or not households have derived demand for fuel types. In this paper, we have proposed a simple model and tested the hypothesis that the demand for fuel is not a derived demand. This finding is consistent with earlier ones in the literature that socio-economic factors may influence choice of fuel types (see e.g., Mekonnen and Köhlin, 2008).

The empirical estimations support our hypothesis after controlling for switching costs and accounting for combustion efficiency of the fuel types. Thus, we found that, all other things being equal, households have strong preferences for some cooking fuels. LPG is the most preferred and kerosene is the least preferred. With the exception of kerosene, the price elasticities of demand for the fuel types examined here are inelastic, and each fuel obeys the law of demand (quantity demanded for each fuel is negatively related to its price and positively related to average income per cluster). The elasticity of demand for kerosene is elastic because, in addition to being a cooking fuel, it is used for lighting.

Further, we found there is spatial distribution of the use of cooking fuels. While LPG is primarily used in the coastal zone, firewood is used more in the savannah zone and kerosene is used more in the savannah and forest zones than in the coastal zone. In order to discourage the use of firewood, government should therefore provide incentives to households in the savannah zone where forest stock per hectare is very low. Since direct subsidies on LPG could generate undesirable consequences, such as leakages and rent seeking by middlemen, LPG bottles and stoves could be subsidized and distributed to households through district assemblies. Most importantly, the fiscal outlays of such a subsidy must be studied to determine if it is worthwhile. The success stories regarding the "butanisation" program in Senegal indicate subsidies could be effective in encouraging households to shift to LPG if they are well targeted.

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**Table 1: Summary statistics of variables used to estimate the demand for each fuel type per cluster**

| Variables | Description | Obs | Mean | Std Dev |
|---|---|---|---|---|
| Liquefied Gas | Average medium size cylinder of LPG used per cluster (measured in kilogram) | 32 | 0.839 | 0.409 |
| Kerosene | Average quantity of kerosene used per cluster (measured in litres) | 240 | 3.229 | 14.212 |
| Firewood | Average bundle of firewood used per cluster (measured in kilogram) | 69 | 2.976 | 2.907 |
| Charcoal | Average mini-bag of charcoal used per cluster (measured in kilograms) | 150 | 0.611 | 2.372 |
| Price per kilojoules of LPG | Average price of LPG used per cluster (¢) | 75 | 14858.670 | 11538.020 |
| Price per kilojoules of Kerosene | Average price of kerosene used per cluster (¢) | 242 | 697.245 | 290.790 |
| Price per kilojoules of Firewood | Average price of firewood used per cluster (¢) | 109 | 928.364 | 536.616 |
| Price of Charcoal | Average price of charcoal used per cluster (¢) | 195 | 8296.496 | 4072.148 |

Data Source: Ghana Living Standards Survey Fourth Round (GLSS4)

**Table 2: Summary statistics of variables used to estimate the demand for fuel per cluster**

| Variables | Description | Obs | Mean | Std. Dev. |
|---|---|---|---|---|
| Energy | Cooking fuel energy types converted to kilojoules | 491 | 176,814.7 | 652,405.8 |
| Expenditure | Total expenditure for both food and non-food items | 1,200 | 3,657,094 | 1,889,805 |
| Prices | Prices of all fuel types pooled together (¢) | 621 | 4,834.367 | 6,815.379 |
| Education | Education level of the respondent measured in years | 1,200 | 1.981 | 0.201 |
| Age | Average age in years | 1,200 | 24.093 | 3.014 |
| Marital Status | Marital Status (1=married and 0=otherwise) | 1,200 | 0.421 | 0.147 |
| Coastal Zone | Ecological zone (1=coastal, 0=otherwise) | 1,200 | 0.347 | 0.476 |
| Forest Zone | Ecological zone (1=forest, 0=otherwise) | 1,200 | 0.453 | 0.498 |
| Savannah Zone | Ecological zone (1=savannah, 0=otherwise) | 1,200 | 0.20 | 0.400 |

Data Source: Ghana Living Standards Survey Fourth Round (GLSS4)

**Table 3**: Demand for kilojoules of cooking energy in Ghana (stacked data)

| Explanatory Variables | Coefficients (1) | Elasticity(1) | Coefficients (2) | Elasticity(2) |
|---|---|---|---|---|
| Log (Price) | **-0.862** *** | **0.862** | **-0.857** *** | **0.857** |
| | (0.079) | | (0.079) | |
| Log ( Average Expenditure) | **0.299** *** | **0.299** | **0.315** *** | **0.315** |
| | (0.067) | | (0.073) | |
| Log (Average Age) | **-0.758** ** | **0.758** | | |
| | (0.355) | | | |
| Proportion Married | -0.058 | | | |
| | (0.219) | | | |
| Coastal Zone (=1, 0 otherwise) | -0.123 | | **-0.179** | **0.069** |
| | (0.098) | | (0.093)* | |
| Forest Zone (=1, 0 otherwise) | -0.064 | | -0.065 | |
| | (0.105) | | (0.092) | |
| Charcoal (=1, 0 otherwise) | **-1.634** *** | **0.499** | **-1.630** *** | **0.498** |
| | (0.136) | | (0.137) | |
| Firewood (=1, 0 otherwise) | **-4.236** *** | **0.637** | **-4.528** *** | **0.636** |
| | (0.268) | | (0.266) | |
| Kerosene (=1, 0 otherwise) | **-4.097** *** | **2.003** | **-4.074** *** | **1.991** |
| | (0.272) | | (0.274) | |
| Constant | 18.999 *** | | 16.289 *** | |
| | (1.521) | | (1.253) | |
| Observations | 491 | | 491 | |
| R-squared | 0.505 | | 0.496 | |

*significant at 10%; ** significant at 5%; *** significant at 1%. Robust standard errors in parentheses

**Table 4**: Demand for kilojoules of firewood, liquefied petroleum gas, charcoal and kerosene in Ghana

| Explanatory Variable | Charcoal | Elasticity | Firewood | Elasticity | LPG | Elasticity | Kerosene | Elasticity |
|---|---|---|---|---|---|---|---|---|
| Log (Price of Charcoal) | **-0.941***** | **0.941** | -0.345 | | 0.466 | | 0.287 | |
| | (0.213) | | (0.805) | | (0.356) | | (0.224) | |
| Log (Price of kerosene) | **0.983**** | **0.983** | 0.277 | | **1.967***** | **1.967** | **-1.296***** | **1.296** |
| | (0.462) | | (0.963) | | (0.467) | | (0.401) | |
| Log (Price of LPG) | 0.115 | | 1.129 | | **-8.907***** | **8.907** | -0.058 | |
| | (0.111) | | (1.005) | | (0.989) | | (0.149) | |
| Log (Price of firewood) | **0.278*** | **0.278** | **-0.874*** | **0.874** | **-0.699**** | **0.699** | 0.318 | |
| | (0.147) | | (0.414) | | (0.255) | | (0.379) | |
| Log (Total Expenditure) | **0.540***** | **0.540** | 0.26 | | **0.701**** | **0.701** | **0.379**** | **0.379** |
| | (0.181) | | (0.392) | | (0.254) | | (0.164) | |
| Savanna zone (=1, 0 otherwise) | -0.198 | | **0.800**** | **0.080** | | | | |
| | (0.197) | | (0.322) | | | | | |
| Coastal zone (=1, 0 otherwise) | | | | | **1.114***** | **0.668** | **-0.514***** | **0.230** |
| | | | | | (0.111) | | (0.173) | |
| Constant | 4.059 | | 5.018 | | 74.369*** | | 10.712** | |
| | (3.231) | | (13.948) | | (10.625) | | (4.856) | |
| Observations | 41 | | 20 | | 20 | | 47 | |
| R-squared | **0.487** | | **0.54** | | **0.68** | | **0.286** | |

*significant at 10%; ** significant at 5%; *** significant at 1%. Robust standard errors in parentheses