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Renewables in the energy transition: Evidence on solar home systems and lighting fuel choice in Kenya

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ABSTRACT

We study the determinants of households' choices of lighting fuels in Kenya including the option of using solar home systems (SHS). Our goal is to add new evidence on the factors that influence the introduction and adoption of decentralized and less carbon-intensive energy sources in developing countries, and, more generally, to the empirical debate on the energy ladder. We capitalize on a unique representative survey on energy use and sources from Kenya, one of the few relatively well-established SHS markets in the world. Our results reveal some very interesting patterns of the fuel transition in the context of lighting fuel choices. While we find clear evidence for a cross-sectional energy ladder, the income threshold for modern fuel use – including solar energy use – to move beyond traditional and transitional fuels is very high. Income and education turn out to be key determinants of SHS adoption, but we also find a very pronounced effect of SHS clustering, i.e. the prevalence of SHS in the proximity of a potential user increases the likelihood of adoption. In addition, we do not find a negative correlation between grid access and SHS use.

1. Introduction

Fuel choices of developing country households are a crucial factor for the adoption of modern energy services and the introduction of decentralized and less carbon-intensive energy systems. In order to increase the use of renewable energy sources, one has to understand how households decide on which fuels to consume. This paper therefore aims to identify the determinants of households' choices of lighting fuels. Our analysis focuses on the use of solar home systems (SHS) in developing countries, as these are a major (off-grid) non-fossil fuel option for lighting.

Since households' energy demand is an important part of overall energy demand, in particular in poorer countries with large rural populations, the choices households make about cooking and lighting fuels have a major impact on the shape of energy systems in those countries. In Kenya, for instance, the majority of households rely on biomass energy for their cooking, lighting and heating needs (Murphy, 2001), with the result that biomass had a share of 74% of Kenya's total primary energy supply (PES) in 2007 (IEA, 2010). Kenya's energy system is typical for many developing countries in that it is very dependent on traditional fuels. These traditional fuels will not be able to support modern economic activities and, hence, act as impediments to faster economic and social development. In addition, their use raises issues such as indoor air pollution and deforestation (Ekholm et al., 2010).

Moving away from traditional biomass to modern energy services may thus foster economic and social development. Furthermore, it is often argued that modern energy services should be based on clean and renewable sources of energy that are abundant in Africa (Brew-Hammond and Kemausuor, 2009), in order to ensure that development will be sustainable. Yet, so far renewables such as geothermal, wind and solar play only a minor role in the provision of developing countries' PES, including in Kenya, where these energy sources accounted for some 6.4% of total PES in 2007 (IEA, 2010). SHS nevertheless constitute a major source of electricity for lighting and other applications in rural Kenya. An estimated 320,000 SHS had been installed in the country by 2010, implying that 4.4% of rural households owned such a system. These systems typically consist of a small solar module of 14–20 W

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peak, some wiring, a rechargeable battery and in some cases a charge-controller. The Kenyan SHS market, which developed largely without the support of the government or donors, is one of the leading off-grid solar markets in the world and the biggest on the African continent. This makes Kenya an ideal case study for the analysis of the adoption of SHS, which are primarily used for lighting, the operation of TVs and radios, as well as the charging of mobile phones (Jacobson, 2007).

Around one fifth of the world's final energy is consumed by electric appliances, which includes lighting (World Bank, 2010), and lighting alone accounts for 19% of global electricity demand (IEA, 2006). In developing countries, lighting is generally thought to rank among the top three uses of energy,[1] with cooking and sometimes space heating of even greater importance (IEA, 2006). While cooking fuel choices have been examined in a number of empirical studies, the choice of lighting fuels has received less attention. In addition, the adoption of renewable energy sources is typically not placed in the context of a specific fuel choice. Yet only in this specific context can renewable adoption or fuel switching be understood well. In Kenya, SHS seem to be used to a significant extent for lighting (Jacobson, 2007). The lack of studies on the adoption of renewables in a particular fuel choice context can partly be explained by a lack of data. Adoption tends to be negligible in most developing countries and nationally representative data on renewables used at the household level is virtually non-existent.

By using data from the Kenya Integrated Household Budget Survey (KIHBS), this paper builds upon a unique dataset to investigate the determinants of the adoption of SHS for lighting in Kenya. The dataset allows for the analysis of the adoption of SHS in the context of fuel choice for a particular activity, in this case lighting. Conceptually, our study builds on the energy ladder concept and we draw on the literature on household fuel choice for cooking. We first review the corresponding theoretical and empirical literature below. Then, we present the results of our empirical analysis. We conclude with a summary of our main results and some policy implications.

2. Previous evidence: The energy ladder hypothesis, cooking fuel choice and solar home system adoption

2.1. The energy ladder hypothesis

One important element of our conceptual framework is the energy ladder hypothesis. This hypothesis assumes that a household's fuel (or energy source) choice depends crucially on the household's income level. As income rises, households move from using traditional fuels, such as wood, first to transitional fuels, like kerosene, and then to modern fuels, such as electricity from the grid (Leach, 1992). Modern fuels are generally perceived to be superior to traditional or transitional fuels in efficiency, comfort and ease of use (Farsi et al., 2007). The concept can thus be seen as a (stylized) extension of the economic theory of the consumer: As income rises consumers demand not only a larger amount of the good, but also change their consumption pattern towards higher quality goods (Hosier and Dowd, 1987).[2]

The observed stark differences in energy-use patterns between poor and rich countries (e.g. Leach, 1992) as well as between households with differing income levels within many (developing) countries motivated the energy ladder hypothesis, which has since been serving as the basis for many empirical applications in the literature (e.g. Gebreegziabher et al., 2011; Heltberg, 2004). Indeed, the empirical literature has confirmed that income is one of the main determinants of household fuel choice and the transition towards modern fuel use. This can partly be explained by the fact that modern fuels often involve a relatively large upfront investment in equipment, which hinders credit-constrained poorer households from using them. In addition, the adoption of modern fuels may require knowledge and a certain level of education, both factors that are correlated with income. On the supply side, there is often a lack of access to markets for modern fuels and the required equipment may not be supplied everywhere.

2.2. Cooking fuel choice

Empirical analyses of household fuel choice for a particular activity almost exclusively investigate cooking fuels.[3] For this household activity the majority of households uses firewood, charcoal, kerosene or electricity, with the specific mix varying depending on the setting (e.g. Farsi et al., 2007; Heltberg, 2004; Hosier and Dowd, 1987; Njong and Johannes, 2011). In the following, we review some evidence on the determinants of fuel choices for cooking fuels in developing country contexts.

Heltberg (2004), for example, investigates fuel switching in urban areas for eight developing countries. He finds a strong link between electrification and the uptake of modern cooking fuels. Other factors that are associated with an increased likelihood of choosing modern fuels are consumption expenditure and education, as well as, in some specifications, the size of the household. In a similar investigation in Guatemala, Heltberg (2005) confirms the relevance of income for fuel choice. He also emphasizes the importance of non-income factors, such as the cost of firewood (as firewood is a widely used cooking fuel in Guatemala). The study shows the widespread prevalence of fuel stacking for cooking purposes in Guatemala and therefore explicitly incorporates two-fuel options in the empirical analysis (e.g. joint wood–liquefied petroleum gas (LPG) use).

Pundo and Fraser (2006) assess cooking fuel choices in the Kisumu district in Kenya. Using the Kisumu Household Survey, which comprises 401 households, they find that the household's cooking fuel choice between firewood, charcoal and kerosene is influenced by education level of the wife, whether or not the household owned the dwelling and the type of house the household lives in. It is worth noting, however, that the authors did not include any income measure in their estimation.

Farsi et al. (2007) take a slightly different approach and also find that income is one of the main factors that prevent households from using modern and cleaner fuels in an application for India based on a household expenditure survey. Additionally, they find education and gender of the household head as well as LPG prices to have an impact on fuel choice. In contrast to Heltberg (2004, 2005) the authors use the fuel that provides the highest share of total useful cooking energy as the dependent variable and order the fuels in terms of efficiency, comfort and ease of use strictly in line with the energy ladder.

Gebreegziabher et al. (2011) assess the determinants of the adoption of electric *mitad* cooking appliances in Northern Ethiopia and its effects on the urban energy transition. The authors analyze the factors that explain urban households' choice of fuel among five options: Wood, charcoal, dung, kerosene, and electricity. Based on survey data the paper finds that the likelihood of electric *mitad* adoption increases with household expenditure, age of household head and family size. Furthermore, fuel choices more generally are found to be determined by prices of substitutes, household expenditure, age and education of household head and family size, with the probability of using transitional and modern fuels (i.e. kerosene and electricity) positively correlated with the price of wood and charcoal, household expenditure and age and education of the household head.[4]

[1] However, a precise estimate of the role of lighting in household energy consumption is generally difficult to obtain (IEA, 2006).

[2] Masera et al. (2000) point out that more expensive technologies are also often perceived to signal higher social status so that one additional aim for moving up the energy ladder is to demonstrate an increase in social status.

[3] See e.g. Foell et al. (2011).

[4] A closely connected approach is used in Jumbe and Angelsen (2011) where the authors focus on the choice of fuel wood collection. They find that it is largely determined by the characteristics of the specific fuel wood source.