Energy Economics 66 (2017) 167–181

Contents lists available at ScienceDirect

Energy Economics

journal homepage: www.elsevier.com/locate/eneeco

A ladder within a ladder: Understanding the factors influencing a household's domestic use of electricity in four African countries

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ARTICLE INFO

Article history:
Received 17 August 2015
Received in revised form 29 March 2017
Accepted 31 May 2017
Available online 8 June 2017

JEL classification:
D12
Q40

Keywords:
Wealth
Education
Access to infrastructure
Energy use
Ladder
Africa

ABSTRACT

According to the energy ladder hypothesis, electricity is at the top of the energy ladder of household energy use that depends primarily on wealth status, income and education levels of the users. However, it is often observed that households with higher income, wealth, and education levels do not use electricity for all domestic activities such as lighting, heating, and cooking, creating a ladder within a ladder. Using a comprehensive data set from the Living Standard Measurement Study from four African countries (Ethiopia, Malawi, Tanzania and Uganda), covering >17,000 households, this paper investigates the factors determining a household's adoption of electricity for lighting only and for lighting and cooking. The results of a multinomial logit model and an ordered probit model show that demographic characteristics, a household's wealth and human capital, access to markets and remoteness greatly accelerate a household's use of electricity for light and cooking, which provides evidence of a ladder within a ladder.

1. Introduction

As per the energy ladder hypothesis, a gradient of quality, convenience and cost can be observed, beginning with solid fuels, such as fuelwood and charcoal at the bottom, to non-solid/liquid fuels such as gas and oil and, finally, with electricity at the top (Leach, 1992). As a result, the use of firewood, dung, and crop waste is prevalent among poor households, while households with better incomes move to the use of electricity and liquefied petroleum gas (LPG) (Behera et al., 2015). This 'energy transition ladder' (Leach, 1975, 1992) elucidates the relationship between income and types of energy used. It postulates that in response to higher income and other factors, households will shift from traditional biomass and other solid fuels to more modern and efficient cooking fuels such as kerosene, LPG, natural gas, or even electricity. Apart from the quantity, the type of energy used also changes with income (Narasimha Rao and Reddy, 2007), with a shift towards modern fuels (Daioglou et al., 2012), in particular, electricity (Hills, 1994). The poor tend to use solid fuels domestically which is damaging the environment and health (Bruce et al., 2000; Holdren et al., 2000; Rehfuess et al., 2006); when income increases, they generally, but not always, switch to cleaner fuels (Masera et al., 2000; Nansaior et al., 2011).

Despite electricity being at the top of the energy ladder (Leach, 1975, 1992), most studies in the past have focused on household energy use patterns (Rao and Reddy, 2007) rather than on an in-depth understanding of the use of electricity by households for two major domestic purposes i.e. light and cooking. Several empirical studies have documented the existence of the energy ladder and/or the factors influencing a household's decision to switch to cleaner fuel with an increase in household income (Özcan et al., 2013). In addition, household demographic features, consumption habits, and gender may play a significant role in a household's energy-choice decisions. Hence, identifying the relative importance of the above factors that influence a household's choice of electricity for light and cooking is critical for policy making in the context of sub-Saharan Africa.

Despite sustained growth during the last decade, a significant proportion of the households in sub-Saharan Africa still use dirty fuels such as firewood, straw, manure and kerosene (although it is better than biomass in terms of convenience and indoor pollution) as sources of energy for light and cooking. In sub-Saharan African countries, the overall electricity access rate is <10%, and in rural areas, it is often <5% (International Energy Agency, 2009). Though electricity is one of the

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http://dx.doi.org/10.1016/j.eneco.2017.05.020
0140-9883/

necessary conditions for development (IEG, 2008), only a small fraction of these households uses electricity for light, and an even smaller fraction uses electricity for cooking and light. Out of 1.317 billion people without electricity, 1.314 billion live in developing countries: 45% of them in sub-Saharan Africa, 37% in South Asia and 14% in China and East Asia (International Energy Agency, 2011). Globally, the urban electrification rate is 90.6%, while it is only 60% in sub-Saharan Africa (SSA); similarly, the global rural electrification rate is 68%, and it is only 14.2% for SSA (International Energy Agency, 2011). The combination of low-income and high up-front connection changes impedes the pace of providing electricity to a larger proportion of the population in SSA. For Ethiopia, Tanzania, and Uganda, the national electrification rates are 17%, 16%, and 12% respectively; the connection charges are US$75, US$297 and US$125 and the connection charge as a percentage of monthly per capita GDP is 50.4% in Ethiopia, 134% in Tanzania and 61.6% in Uganda (Golumbeanu and Barnes, 2013).

The contributions of this research to the current body of literature are as follows. First, no such energy study has been carried out using large nationally-representative household datasets from four African countries covering over 17,000 households. Second, to our knowledge, this is perhaps the first endeavor to investigate the ladder-within-a-ladder for the use of electricity for light and cooking using rigorous econometric models in a low-income setting such as SSA. A multinomial logit model has been used to ascertain the factors influencing a household's use of electricity for only light, and light and cooking. This paper uses the ordered probit model to examine the factors affecting the ranking of the household on the use of clean energy: the households that do not use electricity at all were rated at the lowest level, those that use electricity only for light were rated at the middle level, and those that use electricity for both light and cooking were rated at the highest level. Finally, the accessibility of a wide-range of variables and the superiority of data that the Living Standard Measurement Study (LSMS) provides permitted numerous robustness tests on the importance and role of household education and wealth on a household's use of electricity for light, and light and cooking.

The paper is organized as follows: Section 2 outlines a comprehensive review of the recent pertinent literature on household energy uses in developing countries; Section 3 provides a background of the countries under study; Section 4 summarizes the data, source and sampling, and the specification of econometric models; Section 5 provides the results and discussions from multinomial logit and ordered probit; in Section 6, the paper provides conclusions with policy implications.

2. Review of related literature

A large body of studies has focused on identifying factors affecting households' choices of energy, which highlights the influence of income, household size and composition, education and gender of household heads, and cultural preferences on energy choice (Heltberg, 2004; Hou et al., 2017; Rahut et al., 2016b; Reddy and Srinivas, 2009; Sudhakara Reddy, 1995); however, only a few studies exist that have focused on sub-Saharan Africa (Mensah et al., 2016; Rahut et al., 2017). A number of studies have stressed the welfare gains from the access to/use of electricity on humanity (Bruce et al., 2000; Duflo et al., 2008; Heltberg et al., 2000; Holdren et al., 2000). Sustainable provision of electricity can free significant amounts of time and labor and promote better health and education; electrification can make a major contribution towards achieving economic and social objectives (World Bank, 2007).

Household wealth is one of the important parameters influencing a household's choice of energy sources (Khandker et al., 2012; Narasimha Rao and Reddy, 2007). Wealthier households have a higher purchasing power and, consequently, those households have a greater willingness to pay for a better quality of fuel, particularly electricity. Hence, with an increase in wealth, a household is more likely to move from dirty energy sources to clean energy sources. Similarly, a study in India found that per capita total household expenditure has the largest positive effect on per capita total energy requirements (Pachauri et al., 2004).

Household energy consumption generally increases with household wealth (Huang, 2015; Kwakwa et al., 2013; Narasimha Rao and Reddy, 2007), which is often measured by farm size and livestock in rural households (Arntzen and Kgathi, 1984; Heltberg et al., 2000). Therefore, an increase in farm size and income from agricultural production can cause a decrease in the collection of fuelwood from the forest when households consume more energy and consequently switch to higher-quality energy sources.

The education level of household members affects household energy choices in two different ways: first, education improves income and, hence, affordability and the opportunity cost of time, making the acquisition of time-saving energy sources more economical and even necessary; second, income increases knowledge and affects cultural and consumer preferences, such as a preference for cleaner energy sources. Therefore, households with an educated head tend to choose cleaner energy because of its convenience of use, health benefits and the opportunity cost of their labor. In India, the education level of the household head has been found to increase a household's interest in choosing a clean and efficient source of energy (Narasimha Rao and Reddy, 2007). In terms of demographics, the number of educated females between 10 and 50 years old in a household has been found to have a positive effect on the choice of a clean source of energy (Pandey and Chaubal, 2011). Households in which the head and spouse have a higher level of education have a greater tendency to use modern energy sources, as these offer significant savings in time (Mensah et al., 2016; Özcan et al., 2013; Reddy and Srinivas, 2009). Therefore, the higher educational attainments in a household empirically predict fuel switching (Heltberg, 2005; Huang, 2015; Pachauri and Jiang, 2008; Rahut et al., 2016b); and increasing levels of education are associated with a higher probability of using modern energy sources, and a lower incidence of solid fuel use (Gregory and Stern, 2014; Heltberg, 2004). Education of the household head and spouse reduces the consumption of fuelwood and other conventional fuels because education prejudices households in favor of modern fuels, and improves the decision-makers' understanding of the costs and benefits of modern energy sources, in particular, the health benefits (Israel, 2002; Rahut et al., 2016a).

Within rural households in India, female members are more involved in collecting firewood from the forest than male members, who are more involved in agriculture, wage earning and in other non-farm employment activities (Heltberg et al., 2000). The presence of a large number of women in the household increases the available labor for the collection of fuelwood and for cooking, thus the likelihood of the household moving to less time-consuming sources of energy is reduced (Heltberg, 2005). However, having young children reduces available labor: the presence of a child below six-years old reduces a household's use of firewood, probably because the time available for wood collection is reduced by the time needed for child care (Nepal et al., 2011).

The provision of electricity has positive implications for female members of a household. Past surveys show varied positive benefits of electrification for women, including an increased scope for evening activities, greater flexibility in organizing domestic activities as daylight is no longer a constraint, improved security, the potential for undertaking income-generating work such as handicrafts, and reduction in time required for collecting water if electrification improves water supply (World Bank, 2007).

When the income level increases in the household, or if a woman heads the household, women's preferences are more likely to be realized. Female household members are the main collectors and users of energy in developing countries, and households are the main users of energy (Farhar, 1998). The role of female household members varies from collecting fuel at low income levels to making decisions on the choice of fuel at high income levels (Reddy and Srinivas, 2009). With the use of clean sources of energy, female members have better health and more time for leisure and family, so when a female member is