

Supplementary file for:

The energy transition patterns of low-income households in South Africa: An evaluation of energy programme and policy

Sylvia Israel-Akinbo, Jen Snowball, Gavin Fraser

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Table A: Variable description and measurement.

Variable names	Variable description and measurement
Dependent variables	
Energy choice for cooking	Outcome1 = traditional energy carrier (less preferred) Outcome2 = transitional energy carrier (moderately preferred) Outcome3 = modern energy carrier (most preferred)
Energy choice for heating	Outcome1 = traditional energy carrier (less preferred) Outcome2 = transitional energy carrier (moderately preferred) Outcome3 = modern energy carrier (most preferred)
Energy choice for lighting	Outcome1 = candles (less preferred) Outcome2 = transitional energy carrier (moderately preferred) Outcome3 = modern energy carrier (most preferred)
Independent variables	
Real income	A continuous variable indicating the monthly household income (adjusted for inflation) in South African Rand
Age	A continuous variable indicating the age of household head in years
Gender	A binary variable indicating the gender of household head 1=female; 0=male
Geographical location	A binary variable indicating the location where household lives 1=urban; 0=rural
Household size	A binary variable indicating the number of people living in a household 1 = small household size (1-4persons); 0=large household size (5persons and above)
Dwelling type	A binary variable indicating the type of household dwelling 1=modern dwelling; 0=non-modern dwelling
Year	A nominal variable representing the year of survey, base=2008 Year 2010 Year 2012 Year 2014

Literature on household energy choice

The demand for energy is growing in developing countries because of rapid population growth, especially in Africa. Household energy with increasing population is an important issue for developing countries, however, access is predicted to continue to worsen (Cai and Jiang, 2008; Niu *et al.*, 2012).

The transition to modern energy sources is one of the larger questions that analysis of household energy has tried to address. A body of literature explores the relevance of household energy transition and the factors that describe the circumstances in which households make their decisions.

Transition patterns by low-income households in developing countries

In developing countries, studies have demonstrated that energy transition patterns amongst low-income households could be unidirectional (energy ladder) or could use multiple fuels (energy stacking). Uganda, Kenya, Ethiopia and Mozambique are middle-income countries where both the energy ladder and stacking models have been confirmed amongst the low-income households.

Lee (2013) presented evidence that the transition pattern amongst the low-income households in Uganda conforms to the energy ladder theory. The study implies that the transitioning of the lower income households to the upper rungs of the energy ladder means that the nation's electricity is affordable.

Lay *et al.*, (2013) found that there are clearly pronounced differences between rural and urban low-income households with respect to the lighting fuel.

Guta (2012) study showed that rural households in Ethiopia exhibit energy stacking behaviour, whereby modern and traditional energy carriers were consumed concurrently and simultaneously. The results suggest that even in urban areas, household tend to increase the number of fuels they use as their income increases instead of completely switching from the consumption of traditional fuels to modern fuels. Thus, households tend to switch to a multiple fuel-use strategy (energy/fuel stacking) as their income rises.

Atanassov (2010) noted that high and middle-income households in Maputo, Mozambique do not abandon the use of wood as their income increases as suggested by the energy ladder model. Furthermore, irrespective of the economic status, all income groups make use of charcoal.

Most research has thus found that the energy stacking model is more realistic than the energy ladder hypothesis in describing the transition of low-income households to modern energy sources (Lee *et al.*, 2015; Mekonnen and Köhlin, 2008; Mizra and Kemp, 2009; Van der Horst and Hovorka, 2008; Van der Kroon *et al.*, 2013). The energy ladder and energy stacking models both assumed the existence of hierarchies in household energy services (Van der Kroon *et al.*, 2013). For example, cooking and heating are the first energy services to be met followed by lighting while another school of thought argues that first kilowatt of electricity is dedicated to lighting while traditional or transitional energy carriers are used for cooking and heating. A range of factors, however, have been identified to influence the energy portfolio of households.

Determinants of household energy choice in developing countries

A large body of literature pointed to income as the main factor influencing energy choices by households (Barnes *et al.*, 2010; Kowsari and Zerriffi, 2011; Leach, 1992; Pachauri, 2004; Van der Kroon *et al.*, 2013; Wuyuan *et al.*, 2008). Households made their energy choices based on available income, so that the higher the income level, the greater is the tendency for households to choose relatively expensive modern energy carriers such as electricity over cheaper traditional or transitional energy (such as kerosene, paraffin, wood and charcoal) (Hosier and Dowd, 1987; Lee, 2013). This indicates that there is a strong correlation between increase in income and the uptake of modern energy carriers.

Household consumption expenditure was often used as a proxy for income (Gebreegziabher *et al.*, 2010; Mekonnen and Köhlin, 2009; Mestl and Eskeland, 2009). Mekonnen and Köhlin (2009) found that households generally increased their spending on all energy carriers as their income increased and that they spent more on modern and transitional energy carriers compared with traditional energy carriers. Pachauri and Jiang (2008) discovered a difference in their case study in the rural and urban areas of India and China using secondary data, where the transition to modern energy carriers did not increase as household expenditure rose. Among urban households, nevertheless, the transition to modern energy types occurred with increases in household expenditure. The differences in energy choice decisions across rural and urban households, according to Ekholm *et al.*, (2010) and Gebreegziabher *et al.*, (2010), provided insights into differing levels of affluence in the rural and the urban populations.

Household size was identified as one of the factors that might affect household energy choice (Barnes *et al.*, 2005; Guta, 2012; Heltberg, 2004; Lay *et al.*, 2013; Rao and Reddy, 2007; Van der Kroon *et al.*, 2013). Barnes *et al.*, (2005) and Guta (2012) respectively found that large households of five or more persons tended to select traditional energy carriers, whereas smaller households of one to four persons tended to choose relatively modern energy carriers. A contrasting finding, however, from Heltberg (2005) and Hosier and Dowd (1987), was that larger households were more likely to move away from traditional energy carriers such as wood and to move towards transitional energy carriers such as kerosene, but there was a smaller likelihood that such households would choose electricity over either wood or kerosene. A possible reason for the finding was that household size was not measured as number of residents but by the number of rooms, which according to Heltberg (2005) was an indicator of the wealth of the household. Therefore, large household size was associated with a move away from wood towards exclusive LPG use.

Gender findings have mainly focused on the labour situation of women (Israel, 2002; Lay *et al.*, 2013; Njong and Johannes, 2011; Lewis and Pattanayak, 2012; Van der Kroon *et al.*, 2013). Njong and Johannes (2011) found that households headed by women were more likely to use firewood for cooking than male headed households. On the other hand, Israel (2002) and Lewis and Pattanayak (2012) reported that women might have stronger preferences for using a modern energy carrier given their involvement in cooking.

The age of the household head, also an influence, led to two opposing effects. Quedraogo (2006) found that the further a household moved up in its lifecycle, the wealthier it became allowing the choice of modern energy carriers over traditional or transitional energy carriers. On the other hand, according to Démurger and Fournier (2011) and Rao and Reddy (2007), older household heads might be conservative, having developed the habit of traditional cooking, thereby restraining the move away from this practice.

Energy consumption was found to vary with household dwelling status, explained in terms of type of dwelling. Suliman (2013) assessed the influence of the type of dwelling on cooking energy carrier in Sudan, while Baiyegunhi and Hassan (2014), in a study conducted in rural households in Kaduna State, Nigeria, also assessed the influence of dwelling type. Both results indicated that dwellers in a house roofed by durable materials like metal, cement fibre, concrete, or brick, avoided roof stain by adopting modern or transitional energy carriers. Most rural households that live in traditional houses that are built with mud bricks and without an internal kitchen were less likely to use modern energy carriers.