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Energy access and the ultra-poor: Do unconditional social cash transfers close the energy access gap in Malawi?

Ther Aung [a], Robert Bailis [b], Thabbie Chilongo [c], Adrian Ghilardi [d], Charles Jumbe [c], Pamela Jagger [a,e,*]

[a] Carolina Population Center, University of North Carolina at Chapel Hill, 123 West Franklin Street, Chapel Hill, NC 27516, USA
[b] Stockholm Environment Institute, 11 Curtis Avenue, Somerville, MA 02114, USA
[c] Lilongwe University of Agriculture and Natural Resources, Bunda College, P.O. Box 219, Lilongwe, Malawi
[d] Centro de Investigaciones en Geografía Ambiental (CIGA) & Laboratorio Nacional de Análisis y Síntesis Ecológica (LANASE), Universidad Nacional Autónoma de México, Antigua Carretera a Pátzcuaro 8701, Morelia, Michoacán 58190, Mexico
[e] School for Environment and Sustainability, University of Michigan, 440 Church Street, Ann Arbor, MI 48109, USA

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ABSTRACT

Despite global progress towards improving energy access, major challenges remain for closing the energy access gap between ultra-poor and better off households, and for reaching ultra-poor and last mile populations. Using data from Malawi, we explore the energy access gap between ultra-poor ($N = 900$) and better-off households ($N = 2666$) from the same communities. Compared to better-off households, ultra-poor households had significantly increased odds of having no lighting (OR = 1.58), and significantly reduced odds of having improved lighting (OR = 0.89), owning an improved firewood cookstove (OR = 0.90), and owning a charcoal stove (OR = 0.86). A sub-set of ultra-poor households in our sample received unconditional social cash transfer program (SCTP) payments from the Government of Malawi. Recipients of SCTP payments had significantly reduced odds of having no source of lighting in the household (OR = 0.21) and were more than three times more likely to own an improved cookstove (OR = 3.64) compared to ultra-poor households that have not received payments. The absolute value of per capita expenditures on energy related goods and services is statistically significantly higher for ultra-poor households that receive social cash transfers. We conclude that ultra-poor households experience greater depth of energy poverty compared to better-off households in the same communities. We also find that unconditional social cash transfer payments contribute to improved energy access for the ultra-poor, suggesting that they are a potentially important strategy for catalyzing energy transitions among the ultra-poor.

Introduction

The importance of access to clean and affordable energy is underscored by its inclusion in the United Nations (UN) Sustainable Development Goals (SDG #7) (UN, 2018), and global efforts including the United Nations *Sustainable Energy for All* Initiative (SEforALL, 2020). There is reason for optimism as the global population without access to electricity fell by 35% between 2000 and 2015 to 1.1 billion in 2016, with much of this progress in Asia's rapidly growing economies (IEA, 2017b). Significant cooking energy transitions are taking place in emerging economies (e.g., China and Indonesia), though the absolute number of people without access to clean cooking has remained constant since 2000 (Jeuland et al., 2021). Approximately three billion people, mainly in low income countries, lack access to clean cooking fuels and technologies (IEA, 2017b). Altogether, 40% of the world's population live in energy poverty without access to both electricity and clean cooking.

Despite progress, major challenges remain for scaling-up energy transitions in the poorest regions of the world. Sub-Saharan Africa has the lowest rate of energy access globally with over 600 million people lacking access to electricity (IEA, 2018). Although low income countries in Asia have the largest absolute number of people (1.9 billion) or 43% of the population using biomass fuels for cooking, sub-Saharan Africa has the largest proportion (84%) of its population without access to clean cooking facilities (IEA, 2017a). Progress on transitions to modern energy are largely limited to urban areas (IEA, 2017a), suggesting that current energy transitions may leave out the ultra-poor and those living in remote or last mile settings (Pachauri, Scott, Lucy, & Shepherd, 2013; Sovacool, 2014; Sovacool & Drupady, 2011). A review of previous household energy programs concluded that the chronically poor are

* Corresponding author at: School for Environment and Sustainability, University of Michigan, 440 Church Street, Ann Arbor, MI 48109, USA.
E-mail addresses: theraung@gmail.com (T. Aung), Rob.Bailis@sei.org (R. Bailis), thabbie.chilongo@bunda.luanar.mw (T. Chilongo), aghilardi@ciga.unam.mx (A. Ghilardi), charlesjumbe@bunda.luanar.mw (C. Jumbe), pjagger@umich.edu (P. Jagger).

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often overlooked by governments developing energy policy and programs because the population is often remote and/or cannot pay for energy services when they become available (Pachauri, Scott, Lucy, & Shepherd, 2013).

Our research focuses on the challenge of improving energy access for the ultra-poor, a subset of people who face obstacles to overcoming energy poverty due to very low income and asset portfolios, labor constraints, disabilities and/or other challenges. Malawi provides a relevant context to study energy access disparities because it is one of the poorest countries in the world. In 2017, approximately 95% of Malawi's rural population had no electricity access and >95% relied on solid fuels including firewood, charcoal and crop residues as a primary source of cooking fuel (NSO, 2017). However, despite widespread limitations on access to modern energy services, recent increases in the availability of low cost solar home systems and other solar technologies provides new opportunities for investment in lighting (Davis et al., 2011; USAID, 2019). Similarly, since the mid-2000s, non-governmental organizations (NGOs) have promoted numerous improved biomass cooking technologies in Malawi, with the aim of moving people away from the traditional or baseline cooking technology, i.e., the 3-stone fire or open fire. The most successful is the *Chitetezo mbaula*, a locally produced portable clay cookstove that improves combustion efficiency, reducing the quantity of fuelwood used to cook a meal (Jagger et al., 2017). The *Chititezo mbaula* retails for $2–3 USD making it accessible to most people in Malawi. It is estimated that over one million *Chitetezo mbaula* have been sold or distributed country wide as of 2019, and that several other improved cooking technologies have entered the market (Drigo, 2019). Jagger and Jumbe (2016) identified significant willingness to adopt fuel saving stoves in rural Malawi (Jagger & Jumbe, 2016). However, even at low prices, expenditures on solar home systems and improved cookstoves may be out of reach for the ultra-poor.

In this study we explore the relationship between poverty and energy access, and evaluate whether receiving unconditional social cash transfer payments improves energy access. Our research questions are: 1) Do ultra-poor households experience greater depth of energy poverty than better-off households; and 2) What demand- and supply-side factors mediate energy poverty for ultra-poor and better-off households? We hypothesize that extreme poverty and energy poverty are highly correlated and self-reinforcing. Third, we explore whether receiving an unconditional social cash transfer payment is associated with enhanced energy access for ultra-poor households. We hypothesize that social cash transfer programs have a modest effect on household investment in improved lighting and cooking technologies. Our study provides empirical evidence of structural differences in energy access between ultra-poor and better-off households living in the same communities, and explores the potential for unconditional cash transfer programs to play a role in energy transitions for ultra-poor populations. We know of no other studies that assess the impact of unconditional cash transfers on ownership of household energy assets and energy expenditures.

Materials and methods

Study design

We identify a sample of ultra-poor households using data on enrollment or planned enrollment in the Government of Malawi's unconditional social cash transfer program (SCTP).[1,2] Ultra-poor households, the beneficiaries of the SCTP, are identified through a rigorous and consistently applied targeting mechanism. To qualify for the SCTP a household must be ultra-poor and labor constrained (Abdoulayi et al., 2016). Ultra-poor status is defined as: 1) those who eat one meal a day or sleep on an empty stomach; 2) have no valuable assets, i.e. livestock, furniture, bicycles, mobile phones (excluding land); 3) rely on begging/assistance from well-wishers; and/or 4) are not receiving assistance from other programs. Being labor constrained is defined as: 1) those with a household head or dependents <18 years or >65 years of age; 2) with a dependency ratio above 1 adult: 3 children/elders; and/or 3) if members are >18 years or <65 years of age but are chronically ill. Generally, 10% of households within a district are classified as ultra-poor and labor constrained, making them eligible to receive an unconditional social cash transfer payment. SCTP payments vary by the size of the household, ranging from 1000 to 6000 Malawi Kwacha (USD $2–6) per month. The primary objectives of SCTP are to reduce poverty and hunger and increase school enrollment (Abdoulayi et al., 2016). Previous evaluations have shown that unconditional cash transfers in Malawi contributed to increased food security, food expenditures (Brugh, Angeles, Mvula, Tsoka, & Handa, 2018; Miller, Tsoka, & Reichert, 2011) and agricultural production (Boone, Covarrubias, Davis, & Winters, 2013). For the purposes of our study, all households within a community that are not targeted for the SCTP are considered to be better-off.[3]

Our study was conducted in three districts in southern Malawi: Mulanje, Thyolo and Chiradzulu (Fig. 1). The Southern Region is the most densely populated region in the country with 244 people/km^2 (NSO, 2018). Relative to the rest of Malawi, and among other countries in the region, southern Malawi has relatively high rates of deforestation and forest degradation (Jagger & Perez-Heydrich, 2016). The combination of low rates of electrification and clean cooking, high population density, and high deforestation rates make southern Malawi an energy poverty hotspot.

Two of our study districts (Mulanje, Thyolo) were purposively selected from among the eight districts in Southern Malawi where the Government of Malawi in collaboration with United Purpose, an international NGO, rolled out an improved cookstove add-on to the SCTP in late 2017. Chiradzulu District borders both intervention districts and provides a most similar comparison/control district. Ultra-poor households are identified for SCTP targeting in all three districts, allowing us to compare ultra-poor and better-off households. Mulanje and Thyolo Districts were selected for roll-out of the SCTP prior to Chiradzulu, allowing us to leverage variation in access to SCTP funds on household investment in energy access. All households in Chiradzulu District, and households in both Mulanje and Thyolo Districts that had not yet received payments serve as a comparison group in our analysis of the impact of SCTP payments on energy access.

Sampling and data collection

Within each study district, we sought to sample representative village clusters (e.g., the unit of targeting activities for the SCTP program) and households. Because of the hypothesized relationship between biomass availability and investment in fuel saving stoves, we stratified all village clusters in the three study districts according to forest cover and recent deforestation/regeneration trends.

Using 30 m resolution Landsat imagery from 2017 we stratified villages into three land use land cover change (LULCC) categories: low forest cover/low deforestation (1); low forest cover/high deforestation (2); and high forest cover/low deforestation (3). Cut-offs between LULCC categories were determined by visually checking scatter plots of forest

[1] The SCTP began in 2006 and as of 2017 had rolled out to 18 out of total 28 districts in Malawi.

[2] Our study uses baseline data from a multi-year program evaluation examining the impact of offering a fully subsidized improved cookstove to SCTP households in rural Malawi. For this analysis we use only the baseline data collected in 2017. The program intended to reach 82,000 SCTP households across the eight districts between 2015 and 2019 (United Purpose, 2018). Results of the impact of the joint SCTP/improved cookstove program are reported in a separate paper (Aung et al., in prep).

[3] The unit of administrative function/targeting of the SCTP is the village cluster, a grouping of villages that are geographically proximate to one another such that no SCTP beneficiary should have to walk more than 5 km to a SCTP payment facility (i.e. school, clinic, government building, etc.).

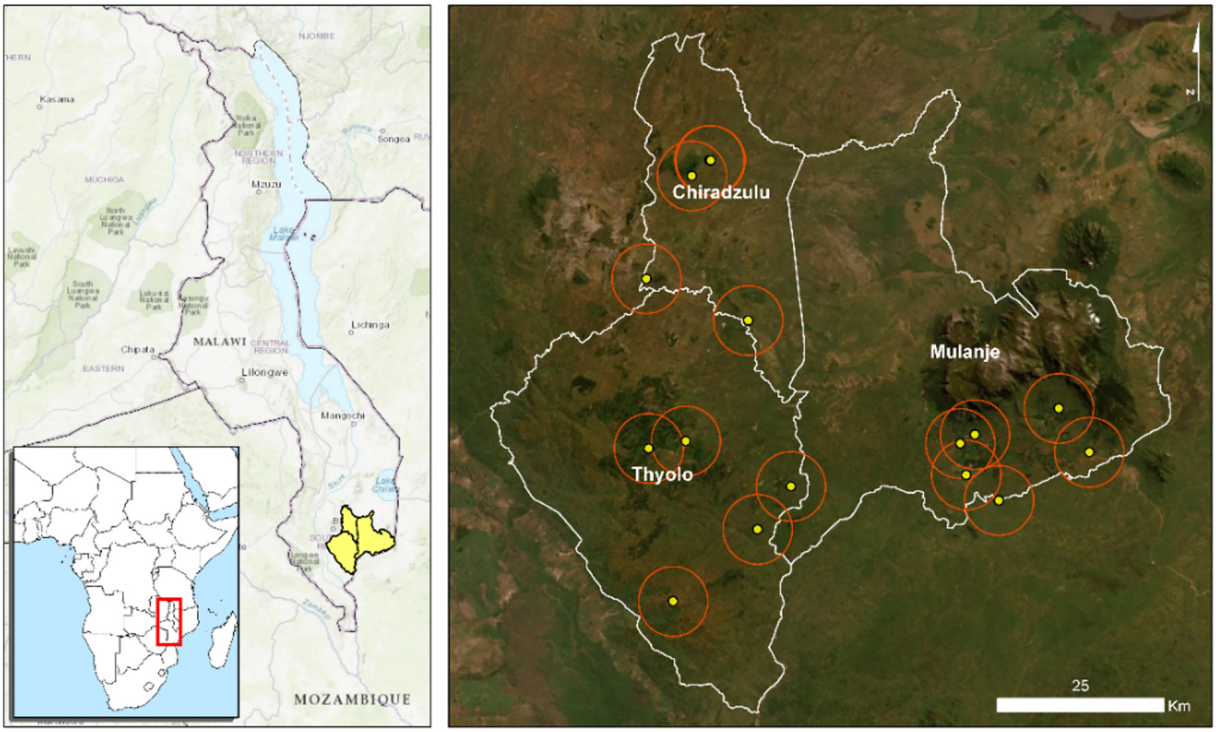

Fig. 1. Map of study sites. Red circles represent 5-km buffer around village clusters. In Chiradzulu, two village clusters are very close to one another overlapping in the above figure.

cover by deforested area percentages within a 3-km buffer around all villages in the study districts. We chose 7% as the cut-off for forest cover; below 7% was considered low forest cover (vs. high >7%). For deforestation rates we examined deforestation rates in the 10 years preceding our study (2008–2017), we chose 22% as the cut-off point; below 22% was considered low deforestation rate and above that was high deforestation. In each district, we randomly selected village clusters within each LULCC category. In total, we selected 16 village clusters (Mulanje = 6; Thyolo = 5; Chiradzulu = 5). Village clusters with similar overall forest cover and deforestation trends were identified from each district (Fig. 1).

For Mulanje and Thyolo Districts, we obtained lists of SCTP registered households from United Purpose with approval from the Government of Malawi. In Chiradzulu, at the time of sampling (June 2017) SCTP lists were not yet available. We replicated the SCTP targeting protocol using community and household derived Household Poverty Lists (HPLs) obtained from the Chiradzulu Social Welfare Officer to draw our sample of ultra-poor households.[4] We sampled a total of 900 households equally divided across the three districts resulting in 50 households per village cluster in Mulanje ($N = 300$), and 60 households per village cluster in Thyolo ($N = 300$) and Chiradzulu ($N = 300$) respectively. Village clusters have approximately 600 households per cluster. We estimate that our sample captured approximately 94% of ultra-poor households in the 16 village clusters we selected for the study.

Our sample of better-off households is a random draw of all other households in the village cluster (i.e., households not targeted for the SCTP or categorized as ultra-poor using HPLs). Enumerators radiated out in randomly assigned transects from the center of the village cluster and recruited households to respond to a short household questionnaire. Our total sample of better-off households is 2666. We had no specific target sample size for better-off households in each village cluster, but asked enumerators to collect data from as many households as they could within the time they were allocated. We interviewed an average of 166 better-off households per village cluster. We estimate that our sample captured approximately 28% of better-off households in the 16 village clusters selected for the study.

We implemented three structured socioeconomic surveys: the ultra-poor household survey ($N = 900$); a rapid survey to better-off households ($N = 2666$); and a village cluster survey ($N = 16$). The ultra-poor survey, administered to SCTP (Mulanje and Thyolo Districts) or SCTP eligible households (Chiradzulu District), included detailed information on household demographics, asset ownership, time use and health status for all members of the household, technologies and fuels used for lighting, cooking, and space heating, household economic activities and income, and expenditures. The rapid household survey administered to better-off households, included a subset of questions from the ultra-poor household survey focusing on household head demographics, energy-related asset ownership, time use, and household energy access. In each village cluster, a short survey was administered to the chief of the primary village in the village cluster including questions about village related demographics and infrastructure, biomass burning activities, and major events/shocks experienced over the past 12 months.

Data were collected in collaboration with the Center for Agricultural Research and Development (CARD) at Lilongwe University of Agriculture and Natural Resources (LUANAR) in Malawi between July and November of 2017. Enumerators were recruited through the CARD network of students and recent graduates. Prior survey experience was an advantage, but not a requirement. Prior to starting data collection, the study team participated in a six-day training workshop at the LUANAR campus covering study objectives, sampling, in-depth review and translation of survey questions, research ethics including recruitment and consent procedures, practicing survey administration using electronic data tablets, and pilot testing the questionnaire in a community near Lilongwe.

[4] The HPLs contain a poverty index score that includes indicators for ultra-poor and labor constrained characteristics and ranks households from "poorest" to "richest". Households that rank "poorest" and "poorer" typically qualify for the SCTP. In each village cluster we sampled all households from the "poorest" category and randomly selected additional households from the "poorer" categories to obtain the target of 60 households per village cluster in Chiradzulu District.

All survey instruments were prepared in English, coded in Open Data Kit (ODK) software, and uploaded into electronic data entry tablets. During training the survey was translated into Chichewa, the language spoken most widely in Southern Malawi. All of the enumerators were bilingual in English and Chichewa, and administered the survey in the local language.

The field team consisted of 10 enumerators and two field managers who oversaw participant recruitment, workflow, community relations, and data quality control. All co-authors spent considerable time in the field. Lead author, Aung, was in the field for the duration of the data collection. Checks on data quality were conducted at two levels. First, the field managers checked data collected by enumerators on the electronic data tablets at the end of every workday and prior to uploading to a secure data server hosted at the Carolina Population Center. Second, a researcher from the study team conducted a second check of the uploaded data soon after, providing opportunities to follow up with questions or clarifications while the data collection team was still in the field.

All subjects gave their informed consent for inclusion before they participated in the study. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Institutional Review Board of the University of North Carolina at Chapel Hill (#17-1952).

Analysis

We calculate means and frequencies to compare indicators of energy access, sociodemographic factors, and community-level variables for two comparison groups. The first compares characteristics between ultra-poor and better-off households. For the second we compare the characteristics, including food, non-food and energy expenditures for ultra-poor households, specifically comparing those who had received SCTP cash payments at the time of our study, and those who had not received any payments. We conduct two-tailed *t*-tests to identify statistically significant difference of means between two groups at each level.

In our multivariate regression analysis, we first consider the role of poverty status (ultra-poor vs. better-off) as a predictor of several indicators of energy access including ownership and use of lighting and cooking technologies. We also consider outcomes relating to access to biomass fuels including household members' self-reported average time and distance travelled one-way to a fuelwood collection site. Our regression analysis is similarly structured for our comparison of ultra-poor households that have received vs. not yet received SCTP payments. We include an analysis of monthly total, food and energy expenditures to understand the role of receiving an SCTP payment on improving energy access.

Our dependent variables are specified as follows. For lighting access, we consider: 1) absence of any lighting in household; and 2) ownership of non-polluting lighting sources (i.e. battery torch, solar powered devices or solar panel and grid). For cooking energy access, we consider: 1) ownership of a metal or clay cookstove; and past 30-day use of 2) charcoal stove; 3) *Chitetezo mbaula*; or 4) other improved cookstove in the household. We focus on fuel efficient/improved stoves because they are expected to reduce the quantity of fuel consumed.[5] Lastly, we consider time spent and distance walked to collect fuelwood as indicators of energy access.

We consider both energy, food, and non-food expenditures in our analyses because the latter two serve as a placebo test for the former. Unconditional social cash transfers are known to contribute to increased food consumption and expenditures (Bhalla, Handa, Angeles, & Seidenfeld, 2018; Haushofer & Shapiro, 2016; Miller, Tsoka, & Reichert, 2011; Tiwari et al., 2016). We expect to see an increase in food expenditure in our analyses. The role of unconditional social cash transfer payments on energy expenditures is not well understood. Per capita expenditures were obtained by dividing the expenditure by number of household members.

To assess what factors predict energy access via ownership and use behavior, binary logistic (logit) multivariate regression was used. The outcome variables were log odds of lighting sources (Eqs. 1 and 2) and log odds of improved cookstove ownership or stove use in past-30 days (Eq. 3). In our lighting models, 'improved lighting' (i.e., using battery torch, solar device, generators or grid connection) is compared to a reference category of 'no lighting' in the household (absence of any lighting, burning grass, or relying on light from cooking fires). For the cookstove models, 1 means ownership or a stove technology used in the past month, and 0 means no ownership or the stove technology not used in the past month (Eq. 3).

$$Y = \log\left(\Pr(\text{No lighting}) \Big/ \Pr(\text{Basic or improved lighting}) \right) \tag{1}$$

$$y = \log\left(\Pr(\text{Improved lighting}) \Big/ \Pr(\text{No lighting}) \right) \tag{2}$$

$$y = \log\left(\Pr(\text{metal or clay cookstove}=1) \Big/ 1 - \Pr(\text{metal or clay cookstove}=1) \right) \tag{3}$$

For analyses of continuous dependent variables, we log-transformed time and distance travelled to a fuelwood collection site and expenditures to normalize skewed data. The models are specified as:

$$Y = g\,(\beta_0 + \beta_1 \text{Ultra-poor} + \beta_2 \text{District} + \beta_3 \text{Household head age} + \beta_4 \text{Household head gender} + \beta_x X + \ldots) + \delta \tag{4}$$

where Y is an outcome of interest, β_0 is intercept, β_1 is ultra-poor or SCTP cash receiving status, β_2 are dummy variables for district, β_3, β_4, …, β_x are coefficients for control variables and δ is error term.

We consider several independent variables in our models. At the household-level we include household size, demographic characteristics of the household head including gender, age, and education, asset, and land ownership. Because assets are one of the criteria used to determine eligibility for the SCTP, we estimate models with and without assets. At the village cluster-level we included variables reflecting distance to nearest market, daily wage rate, and access to forest resources measured by presence of a private or government/communal forest in the village and above ground biomass in the 3-km radius of the primary village. Due to wide range of values for daily wage rate and above ground biomass variables compared to binary variables in the model, we divided the variables by 100 and 1000, respectively to allow for easier interpretation of the coefficients. We also control for district level fixed effects by including district dummy variables in our models.

All models include robust standard errors at the village cluster level to allow for intragroup correlation. We assume observations are independent across village clusters but not necessarily within village clusters. We checked for multicollinearity using variance inflation factor (VIF) and VIFs were below 10 in all models. We employed diagnostic tests to check for goodness of fit using Bayesian Information Criterion (BIC), and Akaike's Information Criterion (AIC) values. The analyses were conducted using STATA 16 SE. All plots were created in Stata using *coefplot* command (Jann, 2014) and blindscheme package (Bischof, 2016).

Results

Energy access

We present indicators of energy access, measured by ownership of modern or improved household energy devices for lighting and

[5] Improved cookstoves might also lead to reductions in household air pollution emissions and exposure, though we note that stoves currently available in the Malawian market have mixed results for emissions reductions (Wathore, Mortimer, & Grieshop, 2017).

cooking, and time and distance travelled to collect fuelwood (Table 1). In the pooled sample of all households irrespective of poverty status ($N = 3566$), 7.3% of households had no lighting inside homes, meaning they used nothing or relied on ambient light from cooking fires. Among those who had a source of lighting, major sources were battery powered torch (57.9%) followed by kerosene lamp (20.3%) and candle (8.4%). Twenty-seven percent of the study population reported ownership of a metal or a clay improved cookstove. However, almost all households (95.3%) reported using traditional three-stone fire as their primary or secondary cookstove in the 30 days prior to our interview, followed by 15% of households who used a charcoal stove. On average, individual household members typically walked an average of 41 min and 2.7 km one-way to a fuelwood collection site.

Our comparison between ultra-poor and better-off households indicates significant differences for several indicators of energy access (Table 1). For lighting, a higher percentage (15%) of ultra-poor households reported having no lighting in their household compared to 5% in the better-off group. A significantly higher percentage of better-off households had access to improved lighting (battery torch, solar devices, including solar home system, torch or panel), and grid electricity compared to ultra-poor households (67% vs. 56%). For cooking technologies, almost twice as many better-off households reported owning a metal or clay improved cookstove compared to ultra-poor households (30% vs. 17%). Similarly, twice as many better-off households reported using alternative stove technologies, such as the charcoal stove (17% vs. 8%) and *Chitetezo mbaula* (4% vs. 2%) compared to the ultra-poor group. Time spent traveling to a fuelwood collection site was similar between the two groups, however, better-off households reported walking slightly longer distances one way to collect fuelwood compared to ultra-poor households (2.8 km vs. 2.6 km, respectively), perhaps due to the labor constrained characteristic of ultra-poor households.

As expected, several socioeconomic and demographic indicators were statistically significantly different between ultra-poor and better-off households (Table 1). Compared to better-off households, ultra-poor households had slightly larger family size (4.8 vs 4.5 persons), older household heads (54 vs. 40 years), and a higher percentage of female headed households (64% vs. 49%). A higher percentage of ultra-poor household heads have no education (35.6% vs. 14.6%) or only lower primary education (34.4% vs. 26.6%) compared to better-off households. Except for land ownership (not considered as a criterion for selection into the SCTP), ultra-poor households own significantly fewer assets, including mobile phones and bicycles. Concrete floors and iron sheets, indicators of well-being, are less common among ultra-poor households. We do not expect or observe significant differences among the study samples at the village level as village clusters are populated by both ultra-poor and better-off households. We note that ultra-poor households were located further from the nearest market compared to better-off households (5.2 km vs. 4.9 km).

Predictors of energy access — lighting

Using the full sample, we assessed household and village cluster predictors for having: 1) no lighting; and 2) improved lighting in the household (Fig. 2; Table SI1). Ultra-poor households had significantly increased odds of having no lighting in their households compared to better-off households (OR = 1.58). Older and female household heads were significantly associated with increased odds of having no lighting in the household. Larger and better educated households and asset ownership were associated with lower odds of having no lighting in the household. Models examining predictors of improved lighting in households, including ownership of a battery torch, solar devices (solar home system, solar torch, solar panel), and grid electricity, indicate that ultra-poor households had lower odds of having improved lighting compared to better-off households (significant in the model omitting assets (OR = 0.76)). Female headed households had lower odds (OR = 0.73) of having improved lighting. Household ownership of assets and land were associated with increased odds of improved lighting in households. Households in Mulanje District (relative to Chiradzulu) had higher odds of having improved lighting.

Predictors of energy access — cooking

For cooking energy technology access, we evaluated both ownership of a metal or clay improved cookstove and use of an improved stove technology over the past 30 days (Fig. 2: Table SI1). Being ultra-poor was associated with lower odds of owning an improved cookstove (OR = 0.62) and past 30-day use of an improved stove (OR = 0.56) in models excluding assets. Having an older household head significantly reduced the odds of owning an improved cookstove (OR = 0.98), use of charcoal stove (OR = 0.98), and other improved stove (OR = 0.99). Education was a significant predictor for ownership of improved cookstove and past month use of a charcoal stove, significantly increasing the odds of improved stove ownership and use. Ownership of assets was significantly associated with increased odds of owning an improved cookstove, and past-month use of charcoal stove or *Chitetezo mbaula*. Village level factors also influence use of improved stoves. Being further away from markets is associated with decreased odds of improved cookstove and charcoal cookstove use. Having a private forest in the village is associated with reduced odds of charcoal stove usage (OR = 0.27), perhaps due to availability of fuelwood, and an over twofold increase in odds of other improved stove usage (OR = 2.81) perhaps due to interest in sustainably using privately owned forest resources. We also note significant differences in stove ownership and use across districts, with much larger odds of using a *Chitetezo mbaula* or other improved stove in Mulanje District, where NGOs have been fairly active in the area of household energy for the past two decades.

Predictors of energy access — access to fuelwood collection sites

We examine variables reflecting access to forest resources, measured by walking time and distance to a fuelwood collection site. In settings where collecting fuelwood for cooking is the norm, proximity to forest resources is a strong indicator of energy access. The following variables were significantly associated with an increase in time and distance travelled to a fuelwood site: household size, age of household head, concrete floor in household, distance to nearest market, presence government or communal forest in the village, amount of land owned (only for ddostamcistance distance), and prsenecnce of private forest in village (only for time) (Table SI1). Being ultra-poor was not statistically significantly associated with increased time spent or distance travelled to fuelwood collection site. Both Mulanje and Thyolo districts were associated with increased time and distance travelled to fuelwood site compared to Chiradzulu.

Relationship between receiving SCTP and energy access

For ultra-poor households, we analyzed differences in energy access and monthly expenditures between households who have ever received SCTP cash payments ($N = 357$) and those who have yet to receive SCTP cash payments ($N = 543$) (Table 1). The percentage of households with no lighting was slightly more than twice for the non-SCTP receiving group compared to the SCTP receiving group (19% vs. 9%). Similarly, 74% of SCTP receiving households had access to improved lighting compared to just 45% of non-SCTP receiving households. Although ownership of a metal or clay improved cookstove was similar between the two groups, a higher percentage of SCTP receiving households reported using the *Chitetezo mbaula* or other improved fuelwood/charcoal stove in the past 30 days. The SCTP receiving group walked 0.62 km further to a fuelwood collection site and allocated more time to fuelwood collection compared to the non-SCTP receiving group.

Using detailed expenditure data for the ultra-poor sample ($N = 900$) we explore the influence of receiving a SCTP payment on household expenditures. Among ultra-poor households, those who have received an SCTP payment have, as expected, higher absolute expenditures

Table 1
Energy access, socioeconomic and demographic indicators for ultra-poor and better off households, and by SCTP receiving status.[1]

Variable	Pooled sample	Ultra-poor	Better-off	Ultra-poor		Min	Max
				SCTP received	SCTP non-received		
Dependent variables							
Lighting							
No lighting (0/1)	0.073	0.152	0.046***	0.090	0.193***	0	1
Basic lighting (0/1)	0.287	0.286	0.288	0.174	0.359***	0	1
Candle (0/1)	0.084	0.061	0.092***	0.025	0.085***	0	1
Kerosene (0/1)	0.203	0.224	0.196*	0.148	0.274***	0	1
Improved lighting (0/1)	0.640	0.562	0.666***	0.737	0.448***	0	1
Battery torch (0/1)	0.579	0.550	0.589**	0.714	0.442***	0	1
Solar (home system; torch; panel) (0/1)	0.040	0.010	0.049***	0.017	0.006*	0	1
Grid electricity (0/1)	0.021	0.001	0.027***	0.003	0.000	0	1
Owns metal or clay cookstove (improved) (0/1)	0.266	0.169	0.298***	0.160	0.175	0	1
Stoves used in past 30 days							
3-Stone fire (0/1)	0.953	0.977	0.945***	0.966	0.98*	0	1
Charcoal stove (0/1)	0.150	0.084	0.173***	0.090	0.081	0	1
Chitetezo mbaula (0/1)	0.036	0.021	0.041***	0.036	0.011***	0	1
Other improved fuelwood or charcoal stove (0/1)	0.038	0.031	0.041	0.048	0.020**	0	1
Fuelwood collection							
Walk time to fuelwood collection site, mins	40.92	39.74	41.31	45.12	36.20***	0	210
	(41.73)	(40.55)	(42.12)				
Distance to fuelwood collection site (one way), km	2.72	2.57	2.77*	2.94	2.32***	0	14
	(2.82)	(2.66)	(2.87)				
Expenditures (per household)							
Total expenditures, MK	13,695	–	–	16,670	11,740	0	173,783
	(13,846)			(14,837)	(12,796)		
Energy expenditures, MK	640	–	–	796	537**	0	27,200
	(1604)			(1775)	(1474)		
Food expenditures, MK	8317	–	–	9549	7507***	0	75,000
	(8364)			(9395)	(7509)		
Energy expenditures per capita, MK/person	161	–	–	174	152	0	7000
	(415)			(306)	(473)		
Food expenditures per capita, MK/person	1958	–	–	2031	1911	0	15,383
	(1908)			(1932)	(1892)		
Other expenditures per capita, MK/person	1099	–	–	1329	948***	0	26,406
	(1678)			(1928)	(1474)		
Independent variables							
Household level							
Ultra-poor status (0/1)	0.252	1	0	1	1	0	1
SCTP payment received during past 12 months (0/1)	0.100	0.397	0	1	0	0	1
Household size, persons	4.56	4.75	4.49***	5.18	4.46***	1	13
	(1.98)	(2.18)	(1.90)	(2.32)	(2.04)		
Age of household head, years	43.71	54.04	40.22***	56.98	52.11***	18	99
	(17.88)	(19.72)	(15.75)	(19.17)	(19.86)		
Female headed household (0/1)	0.528	0.644	0.490***	0.720	0.595***	0	1
Household head education							
No education (0/1)	0.199	0.356	0.146***	0.406	0.322**	0	1
Lower primary (0/1)	0.286	0.344	0.266***	0.389	0.315**	0	1
Upper primary (0/1)	0.348	0.216	0.394***	0.171	0.245***		
Secondary and above (0/1)	0.167	0.084	0.195***	0.034	0.118***	0	1
Concrete floor (0/1)	0.134	0.048	0.162***	0.045	0.050	0	1
Iron sheet roof (0/1)	0.559	0.360	0.627***	0.457	0.297***	0	1
Owns mobile phone (0/1)	0.331	0.182	0.383***	0.199	0.171	0	1
Owns bicycle (0/1)	0.216	0.101	0.254***	0.157	0.064***	0	1
Owns solar panel/torch/system (0/1)	0.073	0.026	0.089***	0.050	0.009***	0	1
Household owns a business that uses woodfuel as an input to production (0/1)	0.215	0.197	0.221	0.204	0.192	0	1
Land owned by household, hectare	0.34	0.37	0.33***	0.46	0.31***	0	2.23
	(0.30)	(0.32)	(0.29)	(0.39)	(0.25)		
Village cluster level							
Distance to nearest market, km	4.96	5.18	4.89**	2.89	6.70***	1	12
	(3.52)	(3.61)	(3.49)	(1.46)	(3.80)		
Daily wage rate, MK	796	788	796	826	763**	500	1900
	(371)	(363)	(374)	(464)	(275)		
Private forest in village (0/1)	0.317	0.323	0.315	0.305	0.335	0	1
Government or communal forest in village (0/1)	0.193	0.180	0.198	0.137	0.208***	0	1
Above ground biomass in 3-km radius of village (tons/ha)	97,560	98,610	97,206	100,900	97,105	33,390	173,511
	(41,665)	(42,429)	(41,407)	(40,111)	(43,858)		
District							
Mulanje	0.378	0.333	0.394	0.831	0.005	0	1
Thyolo	0.299	0.334	0.288	0.168	0.444	0	1
Chiradzulu	0.322	0.332	0.319	0	0.551	0	1
Number of observations	3566	900	2666	357	543	3566	

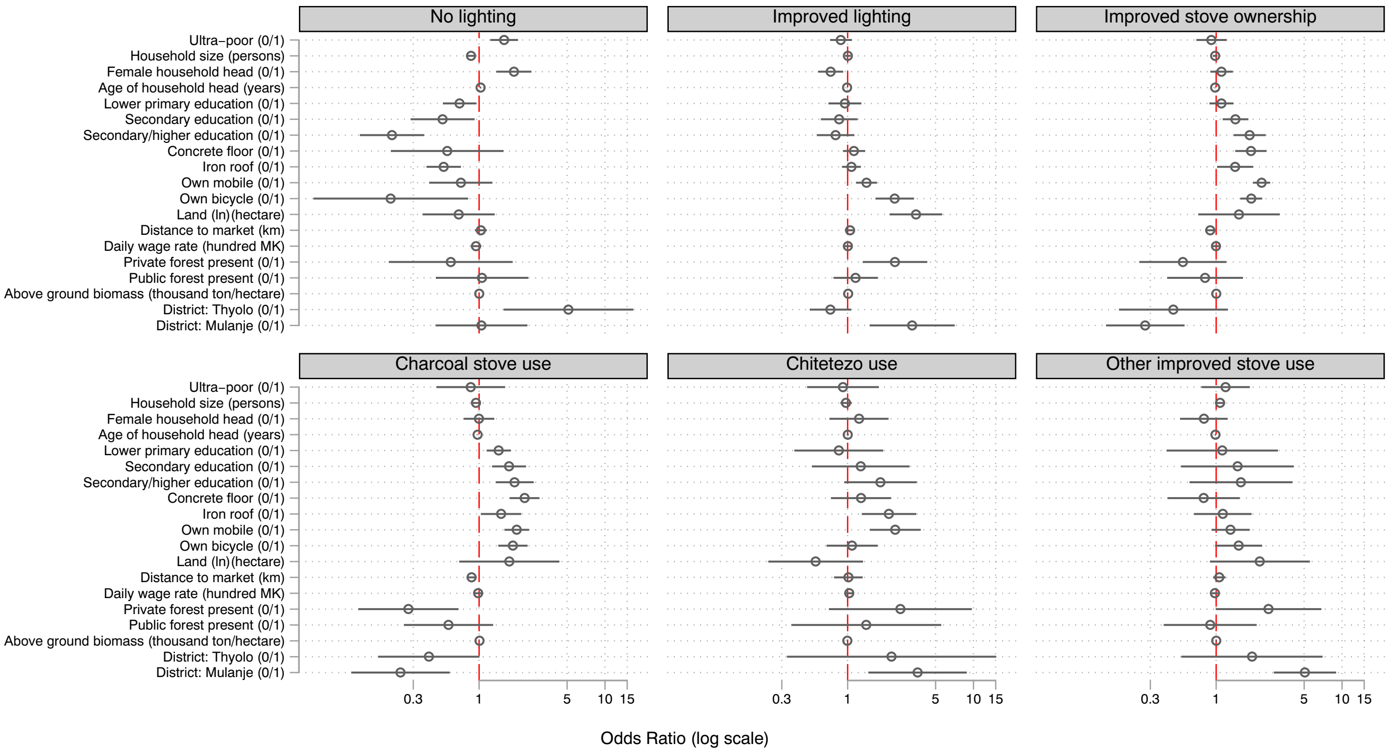

Fig. 2. Adjusted odds ratio for improved lighting and cookstove ownership and use by poverty status.

(Table 1). Analysis of relative shares of household expenditures in the past 30 days reflect the importance of food and non-food staple goods (e.g., soap, washing power, lotion, cigarettes etc.) for non-SCTP receiving (82%) and SCTP receiving households (75%) (Fig. 3). Energy expenditures, though statistically significantly different in absolute terms represent approximately 5% of total expenditure budget for both SCTP receiving and non-receiving households.

Due to differences in household size between the SCTP receiving and non-receiving groups, we estimated per capita spending for three major expenditure categories: energy, food and non-food items. Per capita expenditures for SCTP receiving households were 14%, 40%, and 6% higher for energy, non-food, and food items, respectively, compared to the non-SCTP receiving households (Fig. 4). These findings suggest that social cash transfer payments are being used to improve energy access, albeit from a very low baseline level of per capita expenditure. Our finding that SCTP receiving households have increased spending on food is consistent with previous studies finding that unconditional cash transfers in Malawi improved food security and increased food expenditures (Brugh, Angeles, Mvula, Tsoka, & Handa, 2018; Miller, Tsoka, & Reichert, 2011).

As illustrated in Fig. 4 we observe a slight increase in the per capita share of past 30-day expenditures allocated to energy related goods and services (14%). We provide further disaggregation of energy expenditures by item (Fig. 5) and find that SCTP receiving households are spending a larger share of household cash on purchased fuels including firewood and charcoal. We also observe a substitution of kerosene and candles for lighting with clean technologies including battery powered torches and solar lanterns.

Within the ultra-poor sample ($N = 900$), we compared energy related asset ownership among those who received an SCTP payment with those who have not yet received SCTPs (Fig. 6; Table SI2). For lighting, SCTP receiving households have significantly reduced odds (OR = 0.21) of having no lighting and a two-fold increase in odds of having an improved lighting source (OR = 2.20) when compared to on-SCTP receiving households, though the latter was not statistically significant. Receipt of SCTP payment was associated with significantly increased odds of owning an improved cookstove (OR = 3.64) and use of a charcoal stove during the past 30 days (OR = 18.01). Receipt of an SCTP payment was associated with a statistically significant increase in spending on food, but controlling for household and village level factors, we do not find an association between receiving an SCTP payment and per capital energy expenditures. Predictors significantly associated with higher per capita energy expenditures were household head with secondary education, assets (iron sheet roof, mobile), and availability of above ground biomass.

Discussion

Our study uses data from a sample of ultra-poor and better-off households in rural Malawi to explore the relationship between poverty and energy access, and to examine the impact of receiving social cash transfer payments on ownership of lighting and improved cooking technologies, and energy expenditures. Research on the correlation between poverty and energy poverty is not new; previous studies have shown disparities in energy access across countries and contexts (e.g., rural-urban, less-remote/more remote) with different levels of socioeconomic development (Karekezi, McDade, Boardman, & Kimani, 2012; Pachauri & Spreng, 2004; Reddy et al., 2000). Our study is unique in that it highlights within community disparities among a population that on the surface may seem relatively homogeneous with respect to

Notes to Table 1:
Value in parentheses is standard deviation.
[1] Indicates statistically significant differences between ultra-poor and non-poor households (column 4) and SCTP and SCTP non-receiving households (column 6).
[*] $p < 0.10$.
[**] $p < 0.05$.
[***] $p < 0.01$.

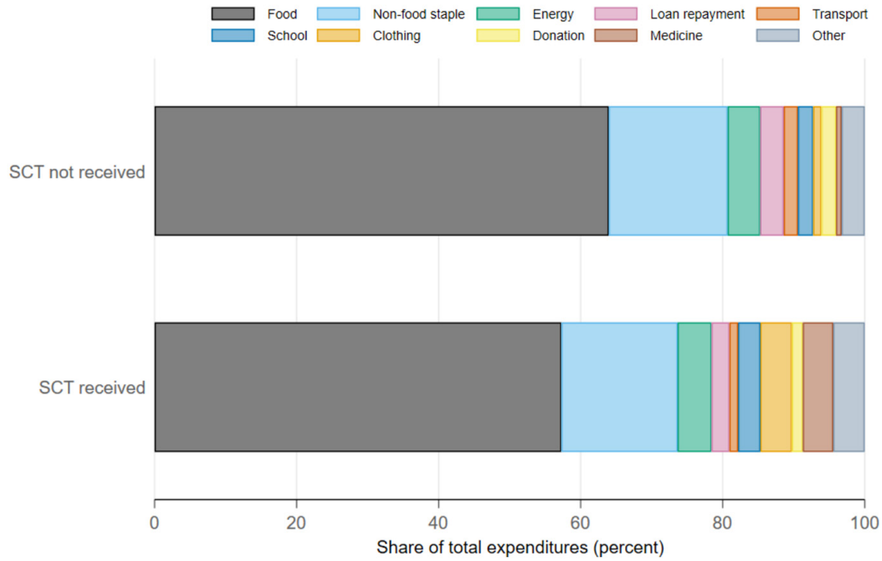

Fig. 3. Relative shares of total household expenditures in the past 30 days by social cash transfer (SCT) received status.

energy access. By focusing on ultra-poor households, our study sheds light on a population that has been little studied to date with regards to their energy needs and living conditions (Pachauri et al., 2012; Pachauri, Scott, Lucy, & Shepherd, 2013; Sovacool, 2014; Sovacool & Drupady, 2011). Our analysis of the impact of SCTP payments on ownership of lighting and cooking technologies and energy expenditures is novel.

Our analysis of lighting is timely given the proliferation of solar technologies in Southern Africa in recent years (Bensch, Peters, & Sievert, 2017). Relatively low-cost solar systems (Pico-PV) and battery powered torches are widely available in local markets. Our study area has relatively good market access with close proximity to Blantyre, the economic center of Malawi. Mulanje is a major market town, and both Mulanje and Thyolo have a large number of tea estates making them relatively well served with respect to availability of goods and services.

We find that ultra-poor households have very different household lighting profiles when compared to better-off households. Ultra-poor households were significantly more likely to have no lighting in the household, and were less likely than better-off households to have a source of improved lighting. Better-off households were more frequent users of candles, a marginal source of lighting, and more likely to use clean energy sources for lighting including battery torches, solar systems, and grid electricity. While the economic impact of these types of minor improvements in lighting is likely negligible, general improvement in quality of life with a clean lighting source likely enhances household well-being. Our analysis of the role of SCTP as a mechanism for improving lighting access is suggestive of an increase in ownership and use of clean lighting technologies. Batteries, solar torches, and solar lanterns were more common expenditures for households that had received payments.

In our study we observe a more complex story with respect to ownership and use of improved cooking technologies. The baseline technology, the three stone fire is used by almost all households. A critical distinction between the traditional and improved technologies is that the three-stone fire is free to the household. Appropriate stones are collected and typically used over a long time period. As noted above, improved biomass stoves have been promoted by several NGOs for decades. The majority of free stove distributions in Southern Malawi

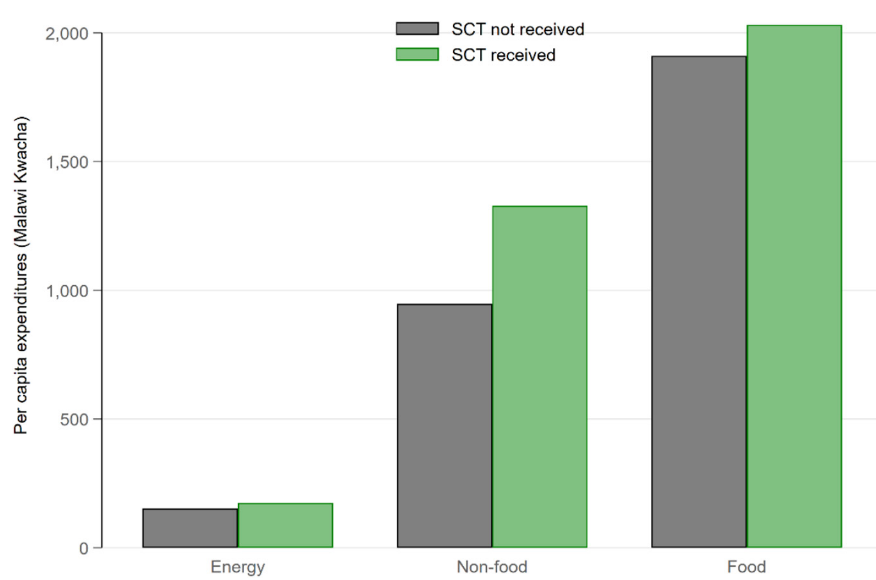

Fig. 4. Per capita expenditures on energy, non-food, and food items in the past 30 days by social cash transfer (SCT) received status.

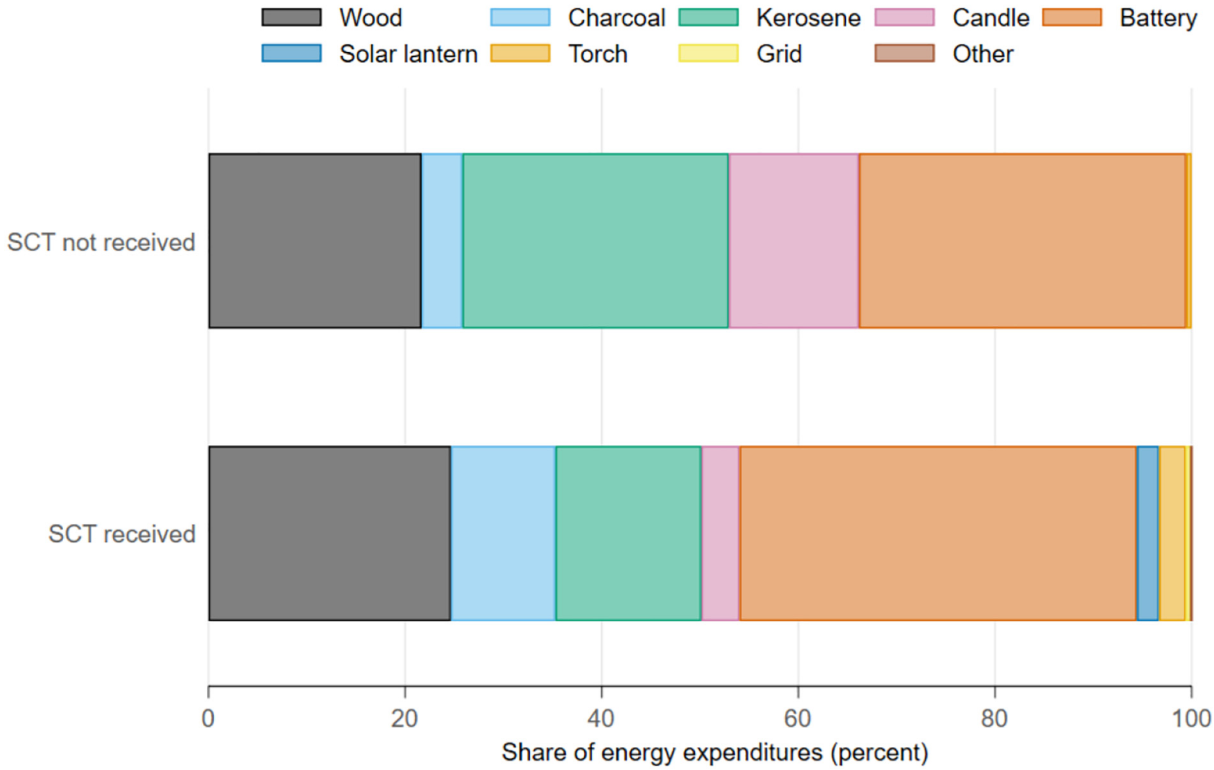

Fig. 5. Relative share of energy expenditures in the past 30 days by social cash transfer (SCT) received status.

has focused on fixed-in-place mud-stoves, often provided by NGOs, church groups and others. Ultra-poor households are more likely to be the focus of those efforts and stove distributions. Other types of improved stoves including portable or fixed improved firewood stoves (e.g. rocket stoves and the *Chitetezo mbaula*) and charcoal stoves are typically purchased for modest amounts (USD $1–10) in local markets.

We find that ultra-poor households were also less likely to own an improved cookstove or to have used a charcoal stove, which typically requires purchased fuel. Improved cookstove ownership is relatively widespread in the better-off population (66% vs. 30% respectively), suggesting that improved energy goods and services are making their way into local markets, but are less accessible to the ultra-poor. We note that ultra-poor households targeted for the SCTP lag behind on take-up of improved cooking technologies, but that receipt of an SCTP payment significantly increases the odds of improved cookstove ownership. A program led by the Government of Malawi and United Purpose rolled

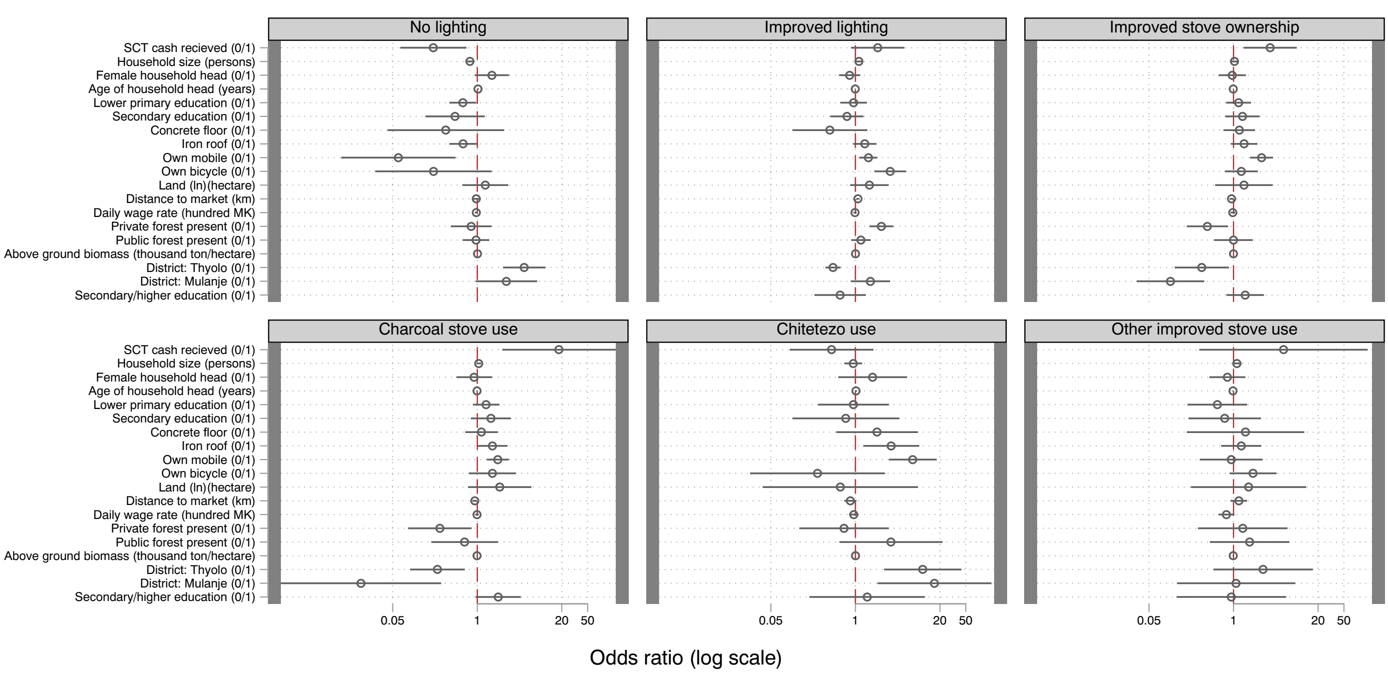

Fig. 6. Adjusted odds ratio for improved lighting and cookstove ownership by social cash transfer (SCT) received status.

out in 2017/18 providing a voucher for a free improved firewood stove (*Chitetezo mbaula*) to all SCTP target households in eight districts in Southern Malawi is an important test-case to see if improved cookstoves can be quickly brought to scale amoung ultra-poor populations. This effort and its' associated impact provide an important test case for coupling SCTP programs with energy access interventions for the ultra-poor. Our analysis of energy expenditure data shows higher relative expenditures on charcoal among households that have received SCTP payments verifying that SCTP payments maybe shifting people up the energy ladder from fuelwood to charcoal use.

Our findings highlighting energy access constraints faced by ultra-poor households are particularly salient given global efforts to meet Sustainable Development Goal 7 '*Ensure access to affordable, reliable, sustainable and modern energy for all*' by 2030. The current focus of most energy access, and energy policy and programming is catalyzing energy transitions with market-based approaches promoting sustainable supply chains driven by private sector investors or social enterprises (Davies, 2018; Quinn et al., 2018; Puzzolo et al., 2019). This approach raises serious questions about how ultra-poor populations will achieve gains in energy access. Ultra-poor populations facing liquidity constraints and last-mile populations with limited access to markets for new energy technologies are particularly at risk (Pachauri et al., 2012). Further, the recent shift in donor and investor attention away from improved biomass stoves and towards promotion of modern fuels and technologies such as liquefied petroleum gas (LPG) (Gould & Urpelainen, 2018; Shen et al., 2018), to meet World Health Organization air pollution guidelines (Simon, Bailis, Baumgartner, & Hyman, 2014), could further exacerbate differences in the trajectory of energy transitions for ultra-poor and better-off households. High cost fuels and technologies exacerbate disparities in energy access and development unless targeted interventions are simultaneously undertaken to promote equitable energy access.

Our study has two notable limitations, the cross-sectional nature of our data and the use of self-reported measures. As noted above, we use baseline data from a quasi-experimental impact evaluation assessing impact of offering a free improved cookstove to all SCTP households in our study area. We use only the baseline data in our analysis as the intervention and associated spillover effects regarding energy access are likely to be significant on the outcome variables we focus our analysis on. As a result, we are unable to make robust casual claims about the relationship between poverty and energy access, and the impact of SCTP cash payments on energy access. Data for our outcome variables are self-reported, which may be subject to bias because of misunderstanding of the question or respondent's desire to answer in a socially desirable way. We have relatively high confidence in reporting on lighting and cookstove ownership and use in the pre-intervention phase of our study, as the incentive to misrepresent household energy status is limited. Social desirability bias is more common for questions related to social taboos, illegal behavior, or attitudes (Krumpal, 2013). Our questionnaire was carefully crafted by adapting questions and measures from national surveys including Malawi's Integrated Household Survey (World Bank Group, 2020), and Multi-Tier Framework Surveys led by the World Bank's Energy Sector Management Assistance Program (ESMAP, 2019).

Conclusion

While progress towards improving access to modern household energy goods and services is being achieved among many populations in low- and middle-income countries, improving energy access for ultra-poor and last-mile populations remains a formidable challenge. In the absence of targeted solutions, access to modern energy for select populations may exacerbate overall measures of poverty and inequality, undermining SDGs focused on those core development outcomes. Our findings highlight disparities between ultra-poor and better-off households, and offer insights into the potential for unconditional cash transfers to improve access to improved lighting and cooking technologies in rural Malawi.

We challenge researchers engaged in evaluations of social protection programs to explore the role of social cash transfer programs and other social protection programs on expenditures for energy related goods and services. Given that unconditional social cash transfer programs are expanding in sub-Saharan Africa, future studies can further elucidate the relationship between energy access and SCTPs through experimental study designs. Lastly, future impact evaluation studies of energy intervention programs should give focused attention to heterogeneous socioeconomic impacts within communities in order to better understand how interventions impact ultra-poor and last mile populations relative to those that are better-off.

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Declaration of competing interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.esd.2020.12.003.

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