Credit, LPG stove adoption and charcoal consumption: Evidence from a randomised controlled trial

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October 2015

When citing this paper, please use the title and the following reference number: E-89225-TZA-1
Credit, LPG Stove Adoption and Charcoal Consumption: Evidence from a Randomised Controlled Trial*

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October 24, 2015

Abstract

The high start-up cost of modern cooking appliances has been shown to be the key factor that hinders transition of households from biomass energy to clean energy in developing countries. We designed a randomised controlled trial to identify the impact of relaxing households’ liquidity constraints on LPG stove adoption and charcoal use in urban Tanzania. In collaboration with a local micro-finance institution, we randomly assigned households into a subsidy treatment and a credit treatment, which included different repayment arrangements. We show that relative to households in the control group, adoption of LPG stoves reduced charcoal use by 47.5% in the treated group. However, providing subsidies for stove purchases resulted in a much larger reduction in charcoal use (54%) than did providing access to credit (41%). We highlight the importance of relaxing households’ financial constraints and improving access to credit to encourage urban households to switch to clean energy sources and save the remaining forest resources of Africa.

JEL Classification: G21, G31, O10, O13, Q23, Q51.

Keywords: Charcoal, LPG Stoves, Deforestation, Liquidity Constraint, Credit

*We would like to thank Håkan Eggert, Andrew Foster, Gunnar Köhlín, Subhrendu Pattanayak, seminar participants at the 8th Environment for Development network (EfD) annual meeting, Dar es Salaam, Tanzania October 23-26, 2014, and the energy research team of the International Growth Center (IGC), based at the London School of Economics (LSE) for useful comments and suggestions at the different stages of this work. The randomised controlled trial in this paper was funded by the IGC, which is gratefully acknowledged. We also gratefully acknowledge financial support from the Environment for Development (EfD) network, based at the Department of Economics, University of Gothenburg and the Gothenburg centre of Globalisation and Development. Part of this research was done while both Alem and Ruhinduka were visiting scholars at Brown University. All errors and omissions are of the ours.

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1 Introduction

Charcoal is the main source of cooking energy for households in urban areas of many Sub-Saharan (SSA) countries (Campbell et al., 2007; Mercer et al., 2011). In the urban parts of Tanzania - the country we focus in this paper - the proportion of households that use charcoal to meet their main cooking needs increased from 47 percent in 2001 to 71 percent in 2007, and a single city Dar es Salaam alone consumes 500,000 tones of charcoal, half of the total annual charcoal consumption of the country (World Bank, 2009). On the other hand, many SSA countries have been experiencing economic growth which resulted in increased income and living standard in urban areas (AfDB, 2014). The fact that charcoal consumption has been increasing with increase in income is contrary to the predictions of the “energy ladder hypothesis”, which has been the key theory in explaining energy transition in developing and emerging countries (Heltberg, 2005; Masera et al. 2000). This theory postulates that households consume biomass fuels such as fuelwood and charcoal at lower levels of income and switch to modern fuels such as kerosene, natural gas, and electricity as their income increases. In this paper, we use a novel randomised controlled trial (RCT) to shed light on the key factors that let households in urban areas of Africa shift from charcoal to Liquified Petroleum Gas (LPG).

Using biomass fuels such as charcoal has serious environmental, health, and climatic implications. The use of charcoal for cooking in urban areas and firewood in rural areas of SSA has been a prime cause of deforestation and forest degradation (Campbell et al., 2007; Brown and Bird, 2008; Mercer et al., 2011), clearly resulting in loss of irreplaceable biodiversity and degradation of local ecosystems (Allen and Barnes, 1985; Geist and Lambin, 2002; Hofstad et al., 2009; Köhlin et al., 2011). Biomass fuelwood use is also associated with indoor air pollution, which claims 3.3% of the global burden of disease, especially that of women and children and about 2 million premature deaths per year WHO (2009). Recent studies also documented that biomass fuel use, often burned in inefficient cookstoves, contributes to climate change through its emission of harmful greenhouse gases including black carbon and carbon dioxide (Sagar and Kartha, 2007; Kandlikar, et al. 2009; Grieshop et al., 2011).

Transition to cleaner fuels is conditional on adoption of appropriate cooking appliances, which can have significant financial implications on poor households who will forgo consumption of other items to acquire them (Edward and Langpap, 2005; Lewis and Pattanayak, 2012). Using carefully executed randomised controlled trials, a few studies (Smith-Sivertsen, 2009; Hanna et al. 2012; Miller and Mobarak, 2013) investigated the factors that promote adoption of improved biomass cookstoves and their impact on indoor air quality, health, and fuelwood consumption in rural areas of developing countries. These studies identify social networks, availability of continuous technical support, cultural factors, and good designs that meet households’ expectations as important factors that promote the adoption and continued use of improved biomass cookstoves. The few existing studies focusing on adoption of modern (clean) cookstoves use observational data (e.g., Edward and Langpap, 2005; Alem et al. 2014) and identify high start-up cost as the key factor that hinders households from switching to appliances that use clean energy such as LPG stoves.

The key question is then whether helping urban households to relax liquidity constraints can
make them switch to modern cookstoves, or whether such dependence on charcoal for cooking is driven by cultural factors that can not be altered by public policy in the short-run. In this paper, we provide the first rigorous evidence on the causal effects of relaxing households’ liquidity constraints on adoption of LPG stoves and on charcoal consumption. We collaborated with Tanzania’s largest micro-finance institution (WAT-SACCO) and randomly allocated households in Dar es Salaam, the largest city in the country, into a “purchase on subsidy” treatment and “purchase on credit” treatment, which constituted three types of credit schemes (payback daily, payback weekly and payback monthly) repayable in six months. To the best of our knowledge, this paper is the first to provide rigorous evidence on the impact of relaxing liquidity constraint of households on adoption of high-cost cooking appliances and on charcoal consumption.

We take advantage of our randomised design to estimate the impact of adoption of LPG stoves through subsidy and the three types of credit schemes on charcoal consumption. Our results indicate that LPG stove adoption overall resulted in a significant reduction in total charcoal use by the treatment group. Specifically, average treatment effects on the treated (ATT) estimates indicate that households in treated communities consumed 47 percent less charcoal compared to the control group four months after the program has been rolled out. This amounted in a reduction in charcoal consumption from 19 kg/week at the baseline to 13 kg/week during the follow-up. However, we find a much larger (54%) reduction in charcoal consumption by households who adopted LPG stoves through subsidy compared to those who acquired them through credit (41%).

Africa’s tropical forests have significant carbon sequestration capacity but are at greater risk than those in other parts of the world, disappearing three times faster than the world average (Mercer et al. 2011). Our findings have significant implications for policies that aim at promoting transition of households to clean energy sources, and saving the remaining forest resources of the continent. Given reducing the startup cost of LPG stoves has significant impact on their adoption and consequently on charcoal use, governments, international donor agencies and other stakeholders should consider channeling resources to improve affordability of LPG stoves to the poor.

The rest of the paper is structured as follows. The next section describes the study area, experimental set-up, and timeline. Section 3 presents descriptive statistics of key variables for both the treatment and control groups. Section 4 presents experimental results on the impact of LPG stove adoption on charcoal consumption, the key outcome variable of interest. Finally section 5 concludes the paper.

2 Experimental Design

2.1 Study Area

Our study was conducted in Kinondoni and Temeke, two of the three districts of Dar es Salaam, the largest city of Tanzania. These two districts are located at the two extreme ends of the city, separated in between by Ilala, a third district. Ilala, which we used for the pilot, is the smallest

1The study by Mercer et al. (2011) actually documents that 30 million ha of Africa’s forest, an area equivalent to the size of Finland, was deforested during 2000-2010, 80% of which was for energy consumption.
district both in terms of geographical size and population.\textsuperscript{2} Dar es Salaam is the most populous region in Tanzania (with nearly 5 million people) and over 70\% of its population uses charcoal as their main source of cooking fuel (NPS 2012). The heavy reliance on charcoal is evident from the open charcoal markets spread throughout the city. Approximately 1 million tonnes of charcoal is consumed for cooking in Tanzania annually and Dar es Salaam city alone consumes half of this amount (World Bank, 2009).

Tanzania has recently discovered huge reserves of natural gas that is expected to play a significant role in the country’s economy by transforming the energy sector and boosting the gross domestic product.\textsuperscript{3} Since 2010, several offshore natural gas discoveries have been made by the BG Group in partnership with Ophir Energy, and Statoil in partnership with Exxon Mobil, reaching around 30 trillion cubic feet of recoverable natural gas reserve. With more discoveries envisaged, a pipeline has been constructed to transport natural gas from Mnazi Bay (the central point of discovery) to Dar es Salaam. These discoveries are expected to significantly reduce the cost of gas and electric energy and create the incentive for households to switch away from charcoal to meet cooking energy needs. However, this transition could be significantly constrained by the relatively high startup cost of modern cooking appliances, especially by the poor households. Findings from the baseline survey, which we present in the next sections support this skepticism. Almost all (99 percent) of households we surveyed stated high level of awareness about LPG stoves and their benefits but felt constrained to not adopt, mainly by their high initial cost.\textsuperscript{4}

Our study is conducted at an important time to provide useful and policy relevant evidence on the constraints of households to adopt modern cookstoves and switch away from charcoal and, what roles public policy can play to tackle them. Given the similarities of many Sub-Saharan African countries with Tanzania in terms of access to energy, the findings from this study will also have significant relevance to other African countries.

\subsection*{2.2 Sample Selection and Design}

In order to conduct our experiment, we chose two wards from each of Temeke and Ilala districts, from a total of 34 and 30 wards respectively. We chose Sandali and Azimio wards from Temeke district, and Manzese and Mwananyamala wards from Kinondoni. The selected wards are residences for a majority of the low income urban households in Dar es Salaam and share similar socioeconomic characteristics but distantly located from each other. The wards benefited reasonably equally from the Community Infrastructure Upgrading Program (CIUP) implemented by the Dar es Salaam city council between 2005-2010. The program involved improving quality of roads, footpaths, drainage, sanitation, solid waste, street lightning, public toilets and drinking water (URT, 2004; URT, 2010).

We approached ward secretaries - government officials responsible for administrating wards under districts - to provide us with the list of all sub-wards, the lowest administrative units in urban areas (also known as streets) ranked by the average economic status of resident households.

\textsuperscript{2}See map of Dar es Salaam in the appendix.
\textsuperscript{3}http://allafrica.com/stories/20150403034.html.
\textsuperscript{4}Currently, less that 4 percent of households in urban Tanzania own a modern cooking stoves such as electric or gas stoves (NPS 2012).
We then selected the top four streets in their rankings in terms of economic status from each ward to participate in our study, which gave us a total of 16 streets. The key argument for selecting households this way is the fact that re-filling LPG gas once the startup gas runs out requires a bulk purchase (as opposed to low cost daily purchase for charcoal, which is common in the city) and thus the targeted population should be able to afford such costs. Finally, we asked the 16 sub-ward leaders to prepare the roster of eligible households in their streets from which we randomly selected a total of 722 households who participated in the baseline survey. Eligibility criteria required that the selected households never owned/used an LPG stove and use charcoal (but not kerosene) as their main source of cooking energy.\textsuperscript{5}

In order to minimise contamination (spill-over effects from treatment groups to the control group), we assigned treatments at street (sub-ward) level. The sampled streets are scattered across the districts and are reasonably large by geographical size and demographics, with average number of households in the sampled streets being about 3000. Street-level randomization also makes implementation of the program relatively easier as it seems fair from households point of view, and politically acceptable by ward leaders. It is therefore important to note that our randomization is done at street-level but the outcome variables of interest are measured at household level.

We are interested in answering three key research questions: first, we want to identify the impact of LPG stoves (regardless of their mode of acquisition) on charcoal consumption, the key outcome variable of interest; second, we are interested in exploring whether the impact on charcoal consumption is different depending on the mode of acquisition (subsidy or credit); and third, we want to assess the degree of stove use and satisfaction in the stoves by households under the two treatments. We thus randomly assigned 5 streets into the credit treatment, 4 streets into the subsidy treatment and kept the remaining 8 streets as the control group. As a result, 216 households were potentially assigned to the credit treatment, 209 to the subsidy treatment and 299 to the control group.

\textbf{2.3 Timeline and Implementation}

We obtained a research permit for this project from the office of Dar es Salaam Regional and Districts Administrative Secretaries, and implemented a fact-finding survey in October-November 2014 on 40 urban households. The aim of this survey was to document both qualitative and quantitative background information on knowledge, adoption and usage (and non-usage) of both LPG and charcoal stoves in all districts, important information that we later use to design our interventions. We designed a short questionnaire and conducted a few focus group discussion sessions that allowed us to obtain informative responses. At this stage, we also included a set of questions on households’ maximum willingness to pay for an LPG stove package and whether they would like to have the stove package on subsidy or on credit and pay for it bit by bit over a certain period. We found encouraging responses from households on knowledge and willingness to adopt LPG stoves, either on credit or subsidy programs. We also found that high start-up cost seemed to be the main factor that hindered households from acquiring the stove.

\textsuperscript{5}The proportion of households that use kerosene gas in Dar es Salaam is only about 7.8\% (NBS 2012).
We conducted a comprehensive baseline survey during March-April, 2015 covering all the 722 sampled households in the 16 sub-wards. In the baseline we included questions on demographic and other socio-economic characteristics, cooking habits, stove use, and awareness and willingness to pay for LPG stoves. This was important information given that the cost of acquiring the stove package is reasonably high and it is natural that some households may not be willing to buy it either on credit or on subsidy. In addition to household-level information, we collected community-level information such as distance to the nearest charcoal market, access to roads etc.

In early May 2015, we conducted a pre-intervention survey to check whether the households who were assigned to the treatment group were willing to buy the LPG stove. During this time, we informed the treatment group that their household has been one of the randomly selected households to receive an LPG stove on subsidy or credit and that the stoves were planned to be delivered approximately 1-2 weeks after the pre-intervention survey. The households were then asked whether they would like to be a part of the program. Only 296 households of the 425 households who were randomly chosen to participate in the program agreed to purchase the stoves, and the remaining 129 households (30%) declined to participate. We later check whether such a refusals to uptake the stoves are likely to bias our sample.

We implemented the LPG stove program in collaboration with a Saving and Credit Cooperative (SACCO) named “Women Advancement Trust” (WAT) which helped us with handling the delivery of the stoves and collection of repayment instalments for the credit treatment households. WAT SACCO is one of the fast growing saving and credit cooperatives that are working to provide access to micro-finance for the urban poor. So far, WAT has gained good reputation and credibility in disbursement and handling of different types of loans including micro credit to finance the purchase of home appliances. In order to make the loan credible and minimize the default rate, we followed all procedures for getting such loans as per the rules of the SACCO, but with a few modifications to suit to the objectives of this study. For example, we did not require households to present any other physical asset as collateral rather than the stove itself. In addition, all credit treatment households were required to pay TZS 20,000 (i.e. 10% of total loan) upfront as their initial re-payment on the day of stove delivery. In addition, they were required to provide a letter of guarantee from from their local government offices, which in Tanzanian context is credible.

The intervention was implemented in late May, 2015. All households selected for the treatments were invited for training before they were handed in the full package LPG stove. The training included instructions on how to safely use, clean, maintain and re-fill the LPG stoves once the startup gas runs out. Households under the credit treatment were provided extra instructions regarding their specific credit scheme including: how to fill-in the application forms, the required documents, how the payments will be collected, etc. All participants were allowed to ask as many questions as they wished and answers were given by the survey team. To minimize associated transaction costs and inconveniences, we required households receiving the stoves on credit to transfer the repayment instalments to a given mobile phone account managed by WAT using their mobile phone banking system. The transfers were set to be done during the working hours of either each working day of the week, every Monday of the week or every 30th day of the month, depending

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6See “http://watsaccos.co.tz” for more information about WAT SACCO.
on the treatment type. The complete loan repayment period was set to be 6 months after delivery of the stove with repayment rates of either TZS 33,350 per month, TZS 8,350 per week or TZS 1,200 per day, depending on the treatment type. We did not charge any interest fee on the loans but required beneficiary households to cover minor transaction fees charged by mobile phone companies during loan repayment.

We then conducted a midline follow-up survey at the end of September 2015 - approximately four months after the stoves have been distributed - to collect information on key outcome variables of interest including charcoal consumption, LPG stove use, compliance to treatment, and satisfaction with the stoves.7

3 Data and Descriptive Statistics

Table 1 presents descriptive statistics of key household socio-economic characteristics, cooking pattern, charcoal use and stated demand for LPG stoves at the baseline. Panel A shows that the average age of the household head is 48 years, the majority of whom (67%) are male, and the average education is 7.1 years of schooling, being slightly higher than the standard primary school level in Tanzania, which is 7 years. About half of the sample households live in privately owned households, but only 41% have access to a separate private kitchen, the remaining either cooking on their corridors or sharing a kitchen with other households. Consistent with our expectation, the majority of our sample households are low income urban dwellers with average reported mean annual income of TZS 309,000 (about USD 172).8 We however notice that the reported average daily expenditure on basic consumption items is TZS 9,600, which on annual basis is nearly eleven times larger than the reported income. This overwhelming difference provides additional evidence that compared to consumption expenditure, income in developing countries is significantly underreported (Deaton, 1997; Deaton and Grosh, 2000). In our subsequent analysis we rely on consumption expenditure to capture economic status of households.

Table 1 about here

There is a large dependence on charcoal to meet cooking energy needs by households in urban Tanzania (Panel B). The average household cooked using charcoal for about 24 years and consumes 18.7 kg of charcoal per week, which costs about 11,000 TZS. We use insights from a recent study to shed light on the devastating consequences of charcoal use in Tanzania. Luoga et al, (2000) show that it requires one hectare of the Miombo woodland forest of Tanzania to produce approximately 3 tonnes of charcoal. Using rough computation, it is easy to show that our sample of households deplete an equivalent to 0.6 ha of forest every week. When it comes to the intra-household decision on the choice of cook stoves, only 47 percent reported that the head is the main decision maker about the type of stoves to be used by the household. This suggests that on average spouses (wives) have a fairly strong intra-household bargaining power when it comes to acquisition of kitchen appliances.

7We initially planned to conduct the mid-line survey six months after the stoves have been distributed. However, the 2015 Tanzania National Election was scheduled in October 2015. In order to avoid interferences in our survey due to election related activities, we instead decided to conduct the mid-line survey in September 2015, four months after intervention.

8At the time of the baseline survey, 1 USD = 1800 TZS.
The type of meals cooked by the household could influence the amount and type of fuel used through the cooking time and taste of food. During the fact finding survey, a few respondents argued that while rice tastes better when cooked on charcoal stove, it takes significantly longer time to boil beans (the main ingredient for the complementary sauce) on the stove. Our baseline data suggests that nearly half of the sample cook rice and beans very often with about 19 meals cooked per week.

Low adoption of LPG stoves in Dar es Salaam seems to be mainly driven by liquidity constraints. Panel C of table 1 reports that 99 percent of the sample households knew about LPG stoves and 80 percent know someone who uses the stove within their close network. However, 93 percent of the the sample households reported the high startup cost of the stove package as the main constraint to their adoption, while 70 percent indicated the cost of refilling LPG gas as a challenge. Difference in taste of food cooked using LPG stoves does not seem to be an important reason for not owning LPG stoves for almost the entire sample. Only 2 percent reported it as the main reason for not owning an LPG stove. This could be partly because none of the households in our sample used an LPG stove previously so they did not experience the taste of food cooked using the stove. This number may change during the endline survey when households are asked the same question after they had experienced cooking using the LPG stove. When asked if they wish to have an LPG stove in the future, in case their economic status improves, a staggering 96% of our sample households replied “yes” but their current average willingness to pay for the stove package is only TZS 63,420, which is much lower than the market price (200,000 TZS) of the stove package in Dar es Salaam.

Randomisation of treatment should insure that on average treatment and control groups have similar baseline characteristics. In order to check this, in table 2, we present means of several key characteristics of households in both groups, as well as test results for the null hypothesis that the difference in means is statistically significantly not different from zero. For nearly all the variables presented, the difference in means is not statistically different from zero. The sole exception is that there is a statistically significant difference in the means of the variable “owning a saving account” between the credit treatment and the control group. Although this is unfortunate, we don’t think it will bias our results since the proportion of households who own a saving account in the control group is about 9 percentage points higher than the credit treatment.

In order to investigate if the decision not to buy the LPG stoves by some of the treatment households resulted in a systematic difference between the treatment and control groups, we performed a simple mean comparison test for all relevant baseline characteristics. Results reported in table 3 indicate that none of the baseline variables seem to be statistically different between the treatment and control groups. Consequently, the decision not to buy by some of the potential treatment group households is less likely to create a bias in our sample.
4 Results

4.1 Charcoal Consumption

Given the randomised nature of our design, we can identify the impact of adoption of LPG stoves on charcoal consumption from the single mean differences between treatment and control groups in an OLS regression. In order to minimise measurement error, during both surveys households were asked to take a record of the quantity of charcoal used during the most recent week in the local units. We visited four charcoal markets in each ward and constructed average conversion factors to standard units by measuring each available local unit using a digital scale. We then converted all local units reported by households into standard units using these conversion factors.

We begin with results from the simple mean comparison of weekly charcoal consumption between the treatment and control groups during the baseline and follow-up as reported in Table 6. Panel A presents the results for the quantity of charcoal consumed. While the two groups reported the same consumption of charcoal per week during the baseline (19 kg), treated households consumed 6 kg less in a week compared to the control households during the follow-up survey, which we conducted four months after the stoves were introduced. This translates into a large reduction in charcoal use which is statistically significant at one percent level. We present the monetary value of the reduction in charcoal due to adoption of LPG stoves in Panel B. The results reveal that adoption of LPG stoves reduced the amount of weekly charcoal expenditure for the treatment group by about 3,800 (USD 2.1) compared to the control group.

Table 4 about here

Table 5 provides formal empirical estimation of average treatment effects on the treated (ATT) from an OLS model. Column (1) presents the results for the impact of adoption of LPG, regardless of the treatment type. In column (2), we extend the analysis by controlling for the type of treatment (subsidy and credit). This is very important from public policy point of view given the ongoing debate that people tend to value and use goods less when they receive them at a lower price (e.g., Hoffman et al., 2008; Hoffman, 2009; Cohen & Dupas, 2010). Consistent with the observation in the mean comparison presented in the previous table, column 1 of table 5 suggests that LPG adoption reduced charcoal consumption by about 47.5 percent per week compared to the treatment group. When we assess the impact by the treatment type, results in column 2 suggest relatively larger impact (54 percent) for the stoves adopted through a subsidy compared to the control group than those purchased on credit (41 percent). The results remain robust even after controlling for other covariates (column 3). We argue that the difference in the impact of LPG stoves acquired between the credit and subsidy treatments could be explained by several factors. The main reason could be the fact that we conducted our midline followup survey four months after the interventions and before households who bought the stoves on credit have paid back the full amount of the LPG loan. It is therefore plausible to expect that the credit households are still hesitant to use the stove relative to those who received the stoves on subsidy and who actually have full ownership. This could be more pronounced by the fact that the stoves themselves are collateral for the credit.

Table 5 about here
4.2 Satisfaction in LPG Stoves

In addition to identifying the impact of LPG stove adoption on charcoal use, it would be interesting to investigate how often adopter households use the stoves and whether the intensity of use differs across treatments. One could anticipate that provision of LPG stoves would encourage households to switch from charcoal to LPG. However, existing empirical evidence (e.g., Masera et al. 2000; Heltberg, 2005) suggest that households may continue to use the charcoal stove in combination with the LPG stove, a phenomenon known as “fuel stacking”. In our sample, almost 25 percent of the treated households (i.e., 74 households) reported not to have used the LPG stove over the past one week during the follow-up survey. In table 6, we explore if stove use and intensity is correlated with the type of treatment assigned to households. Results suggest that the number of times the stove is put in use is not correlated with the treatment category. These results are robust to controlling for other covariates. We however find education (years of schooling) to be positively correlated with the intensity of LPG stove use.

Table 6 about here

We finally explore to what extent households who received LPG stoves are satisfied with the different attributes. Figure 1 shows the distribution of responses to the satisfaction questions. Results suggest that the majority of households are satisfied with all features of the stove including, stove quality (80 percent), stove functioning (79 percent), gas cost (77 percent), food taste (73 percent) and cooking convenience (80 percent). These results indicate that the type of LPG stoves we distributed have high acceptance rate by sample of treated households in urban Tanzania.

Figure 1 about here

In order to explore the correlates of reported levels of satisfaction with the different attributes of LPG stoves, we run simple OLS models of satisfaction and report the regression results in table 7. Two variables appear to be consistently important correlates of satisfaction in LPG stoves, household size and years of schooling. Households headed by educated individuals are satisfied with all aspects the LPG stoves. Larger households are satisfied with all aspect of the stove except with functioning. We however do not find any evidence suggesting satisfaction in stove attributes is correlated with the type of treatment, as indicated by coefficient of the credit treatment variable, which is statistically insignificant.

Table 7 about here

5 Conclusions

Charcoal, largely consumed by households in urban areas, has been documented to be one of the main causes of deforestation and forest degradation in Africa. Forest clearing for charcoal production resulted in loss of invaluable biodiversity and destruction of local ecosystems. One important factor that hinders transition of households from biomass energy to clean energy sources is the high start-up cost of modern cooking appliances. In order to test for this hypothesis, we collaborated with one of Tanzania’s largest micro-finance institutions, WAT-SACOS, and implemented an LPG

9See table A1 in the appendix for the distribution of reasons for not using the stoves
gas stove program in a randomised controlled trial setup. The program involved provision of a durable and high-quality two-burner LPG stove package on subsidy and credit, which included different repayment arrangements. To the best of our knowledge, this is the first study to provide rigorous evidence on the causal effects of relaxing households financial constraints on adoption of modern cooking appliances with high start-up cost and charcoal consumption.

The LPG stoves we offered had high uptake rate by urban households in Tanzania with 70 percent of those who were randomly assigned to the treatments adopting them. Our results indicate that, overall, adoption of LPG stoves reduced charcoal consumption by about 47.5 percent per week compared to the control group. When we assess the impact by the treatment type, estimates suggests that compared to the control group, those who adopted the stoves through a subsidised price reduced charcoal consumption by 54 percent while those who adopted the stoves on credit reduced charcoal consumption by 41 percent. These results are robust for controlling other household covariates. This finding is consistent with the reported use frequency by households, with those who obtained the stoves through subsidy using them more often than those who obtained them on credit. The possible explanation for the difference in stove use and impact on charcoal consumption was most likely driven by the fact that the follow-up survey took place a couple of months before the full credit amount has been paid out by households, who probably did not feel complete ownership of the LPG stoves.

Millions of hectares of Africa’s forests are destroyed for production of charcoal and firewood each year. Given the documented high carbon sequestration potential of Tanzania’s forests, targeting reduction of charcoal production would have a much larger external benefits to society at large. The findings from our study provide useful insights on how to reduce charcoal consumption in urban areas of Africa. Both the descriptive statistics and results from our randomised controlled trial demonstrate that the high start-up cost of modern cooking appliances such as LPG stoves is the main factor that prohibits households from switching to modern and environmental-friendly energy. In view of this, simple policy interventions such as reducing the import duty of LPG stoves could increase adoption and use of LPG stoves and consequently reduce charcoal consumption. This is the main message that originates from our study, which could be useful to policymakers, donors, and other stakeholders who are interested in saving the remaining forest resources of Africa.
Figure 1: Satisfaction with different features of LPG stoves

Appendix
References


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## Table 1: Descriptive Statistics at Baseline

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Panel A: Socioeconomic Characteristics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>48.004</td>
<td>13.351</td>
</tr>
<tr>
<td>Male</td>
<td>0.670</td>
<td>0.470</td>
</tr>
<tr>
<td>Household size</td>
<td>5.768</td>
<td>2.222</td>
</tr>
<tr>
<td>Annual income (TZS)</td>
<td>309931.00</td>
<td>256702.70</td>
</tr>
<tr>
<td>Years of schooling</td>
<td>7.165</td>
<td>3.076</td>
</tr>
<tr>
<td>Muslim (dummy, 1= yes)</td>
<td>0.793</td>
<td>0.405</td>
</tr>
<tr>
<td>Has access to main grid electricity in the house (dummy, 1= yes)</td>
<td>0.750</td>
<td>0.433</td>
</tr>
<tr>
<td>Average household daily expenditure</td>
<td>9661.586</td>
<td>18043.120</td>
</tr>
<tr>
<td>Access to separate kitchen room (dummy, 1= yes)</td>
<td>0.406</td>
<td>0.491</td>
</tr>
<tr>
<td>Residential house in privately owned (dummy, 1= yes)</td>
<td>0.505</td>
<td>0.500</td>
</tr>
<tr>
<td>At least one member owns a saving account (dummy, 1= yes)</td>
<td>0.373</td>
<td>0.484</td>
</tr>
<tr>
<td><strong>Panel B: Cooking Pattern and Charcoal Use</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of years using charcoal stove</td>
<td>23.748</td>
<td>11.662</td>
</tr>
<tr>
<td>Head decides on acquisition of stove (dummy, 1= yes)</td>
<td>0.469</td>
<td>0.499</td>
</tr>
<tr>
<td>Distance to nearest charcoal market (in minutes)</td>
<td>4.349</td>
<td>4.224</td>
</tr>
<tr>
<td>Number of meals cooked last week</td>
<td>18.885</td>
<td>3.560</td>
</tr>
<tr>
<td>Number of meals cooked last week using charcoal</td>
<td>16.073</td>
<td>4.698</td>
</tr>
<tr>
<td>Rice, main staple for the household (dummy, 1= yes)</td>
<td>0.477</td>
<td>0.500</td>
</tr>
<tr>
<td>Beans, main sauce (dummy, 1= yes)</td>
<td>0.551</td>
<td>0.498</td>
</tr>
<tr>
<td>Amount of charcoal used last week (in Kg.)</td>
<td>18.719</td>
<td>10.049</td>
</tr>
<tr>
<td>Total expenditure on charcoal last week (in TZS)</td>
<td>109480.030</td>
<td>6107990</td>
</tr>
<tr>
<td><strong>Panel C: Demand for LPG stoves</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Household knows about LPG stoves (dummy, 1= yes)</td>
<td>0.985</td>
<td>0.123</td>
</tr>
<tr>
<td>Knows someone using LPG stove (dummy, 1= yes)</td>
<td>0.803</td>
<td>0.398</td>
</tr>
<tr>
<td>High start up cost is main reason for not owning LPG (dummy, 1= yes)</td>
<td>0.934</td>
<td>0.249</td>
</tr>
<tr>
<td>Higher cost of refilling is main reason for not owning LPG (dummy, 1= yes)</td>
<td>0.701</td>
<td>0.458</td>
</tr>
<tr>
<td>Difference in taste of food cooked is main reason for not owning LPG (dummy, 1= yes)</td>
<td>0.024</td>
<td>0.152</td>
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<tr>
<td>Household wishes to own LPG stove in the future (dummy, 1= yes)</td>
<td>0.961</td>
<td>0.193</td>
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<tr>
<td>Maximum willingness to pay for an LPG stove package (TZS)</td>
<td>63419.670</td>
<td>38548.520</td>
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<tr>
<td>Affords gas refilling cost (dummy, 1= yes)</td>
<td>0.882</td>
<td>0.323</td>
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<td>Walking distance to the nearest LPG gas dealer (in minutes)</td>
<td>17.757</td>
<td>14.102</td>
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<td>Observations</td>
<td>722</td>
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Table 2: Descriptive Statistics by Treatment Type

Panel A: Socioeconomic Characteristics

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<th>1 - Credit</th>
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<th>3 - Control</th>
<th>Diff. 1 Vs 3</th>
<th>Diff. 2 Vs 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>47,769</td>
<td>47,048</td>
<td>47,451</td>
<td>0.317</td>
<td>-0.403</td>
</tr>
<tr>
<td>Male</td>
<td>0.694</td>
<td>0.660</td>
<td>0.717</td>
<td>0.451</td>
<td>-0.023</td>
</tr>
<tr>
<td>Household size</td>
<td>5.644</td>
<td>5.799</td>
<td>5.997</td>
<td>-0.353</td>
<td>-0.198</td>
</tr>
<tr>
<td>Annual income in TZS (log)</td>
<td>12,486</td>
<td>12,427</td>
<td>12,496</td>
<td>-0.010</td>
<td>-0.069</td>
</tr>
<tr>
<td>Years of schooling</td>
<td>7.602</td>
<td>7.565</td>
<td>7.404</td>
<td>0.198</td>
<td>0.161</td>
</tr>
<tr>
<td>Access to main grid electricity (dummy, 1= yes)</td>
<td>0.745</td>
<td>0.809</td>
<td>0.811</td>
<td>-0.066</td>
<td>-0.003</td>
</tr>
<tr>
<td>Average household daily expenditure</td>
<td>8877,315</td>
<td>10545,450</td>
<td>9168,350</td>
<td>-291,035</td>
<td>1377,100</td>
</tr>
<tr>
<td>Separate kitchen (dummy, 1= yes)</td>
<td>0.421</td>
<td>0.368</td>
<td>0.515</td>
<td>-0.043</td>
<td>-0.032</td>
</tr>
<tr>
<td>Residential house privately owned (dummy, 1= yes)</td>
<td>0.472</td>
<td>0.500</td>
<td>0.515</td>
<td>0.011</td>
<td></td>
</tr>
<tr>
<td>Saving account (dummy, 1= yes)</td>
<td>0.366</td>
<td>0.469</td>
<td>0.458</td>
<td>-0.092**</td>
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Panel B: Cooking Pattern and Charcoal Use

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<th>3 - Control</th>
<th>Diff. 1 Vs 3</th>
<th>Diff. 2 Vs 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of years using charcoal stove</td>
<td>23,736</td>
<td>22,737</td>
<td>22,987</td>
<td>0.750</td>
<td>-0.250</td>
</tr>
<tr>
<td>Head decides on acquisition of stove (dummy, 1= yes)</td>
<td>0.472</td>
<td>0.435</td>
<td>0.421</td>
<td>0.051</td>
<td>0.015</td>
</tr>
<tr>
<td>Distance to nearest charcoal market (in minutes)</td>
<td>4,512</td>
<td>4,696</td>
<td>4,236</td>
<td>0.276</td>
<td>0.460</td>
</tr>
<tr>
<td>Number of meals cooked last week</td>
<td>19,222</td>
<td>16,292</td>
<td>16,364</td>
<td>0.101</td>
<td>0.242</td>
</tr>
<tr>
<td>Number of meals cooked last week using charcoal</td>
<td>16,759</td>
<td>16,292</td>
<td>16,364</td>
<td>0.396</td>
<td>-0.072</td>
</tr>
<tr>
<td>Rice, main staple for the household (dummy, 1= yes)</td>
<td>0.537</td>
<td>0.502</td>
<td>0.488</td>
<td>0.049</td>
<td>0.014</td>
</tr>
<tr>
<td>Beans, main sauce (dummy, 1= yes)</td>
<td>0.560</td>
<td>0.488</td>
<td>0.522</td>
<td>0.038</td>
<td>-0.034</td>
</tr>
<tr>
<td>Amount of charcoal used last week (in Kg.)</td>
<td>19,088</td>
<td>18,482</td>
<td>19,734</td>
<td>-0.646</td>
<td>-1.252</td>
</tr>
<tr>
<td>Total expenditure on charcoal last week (in TZS)</td>
<td>11137,440</td>
<td>4921,571</td>
<td>11498,890</td>
<td>-361,450</td>
<td>-694,360</td>
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</table>

Panel C: Demand for LPG stoves

<table>
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<tr>
<th></th>
<th>1 - Credit</th>
<th>2 - Subsidy</th>
<th>3 - Control</th>
<th>Diff. 1 Vs 3</th>
<th>Diff. 2 Vs 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household knows about LPG stoves (dummy, 1= yes)</td>
<td>0.981</td>
<td>0.990</td>
<td>0.983</td>
<td>0.129</td>
<td>-0.002</td>
</tr>
<tr>
<td>Knows someone using LPG stove (dummy, 1= yes)</td>
<td>0.819</td>
<td>0.804</td>
<td>0.791</td>
<td>0.047</td>
<td>0.028</td>
</tr>
<tr>
<td>High start up cost of LPG (dummy, 1= yes)</td>
<td>0.949</td>
<td>0.914</td>
<td>0.936</td>
<td>0.245</td>
<td>0.013</td>
</tr>
<tr>
<td>High cost of refilling (dummy, 1= yes)</td>
<td>0.704</td>
<td>0.699</td>
<td>0.700</td>
<td>0.459</td>
<td>0.003</td>
</tr>
<tr>
<td>Difference in taste of food (dummy, 1= yes)</td>
<td>0.037</td>
<td>0.014</td>
<td>0.020</td>
<td>0.141</td>
<td>0.017</td>
</tr>
<tr>
<td>Max. willingness to pay for an LPG stove (TZS)</td>
<td>64199,070</td>
<td>67263,160</td>
<td>60148,150</td>
<td>4050,920</td>
<td>7115,010</td>
</tr>
<tr>
<td>Affords gas refilling cost (dummy, 1= yes)</td>
<td>0.889</td>
<td>0.904</td>
<td>0.862</td>
<td>0.346</td>
<td>0.027</td>
</tr>
<tr>
<td>Distance to the nearest LPG gas dealer (in minutes)</td>
<td>18,951</td>
<td>16,145</td>
<td>18,022</td>
<td>14,081</td>
<td>0.930</td>
</tr>
</tbody>
</table>

Notes: **p < 0.01, *p < 0.05, p < 0.1.
Table 3: Descriptive Statistics by Treatment Type: Accounting for Uptake

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<tr>
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<th>[Control]</th>
<th></th>
<th>[Diff.]</th>
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<td>Coeff.</td>
<td>SE</td>
<td>Coeff.</td>
<td>SE</td>
<td>Coeff.</td>
<td></td>
</tr>
<tr>
<td><strong>Panel A: Socioeconomic Characteristics</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>47,236</td>
<td>12,183</td>
<td>47,505</td>
<td>12,812</td>
<td>-0.269</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>0.661</td>
<td>0.474</td>
<td>0.721</td>
<td>0.449</td>
<td>-0.060</td>
<td></td>
</tr>
<tr>
<td>Household size</td>
<td>5,712</td>
<td>2,173</td>
<td>5,997</td>
<td>2,258</td>
<td>-0.284</td>
<td></td>
</tr>
<tr>
<td>Annual income in TZS (log)</td>
<td>12,494</td>
<td>0.733</td>
<td>12,495</td>
<td>0.696</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>Years of schooling</td>
<td>7,642</td>
<td>3,127</td>
<td>7,404</td>
<td>2,711</td>
<td>0.238</td>
<td></td>
</tr>
<tr>
<td>Average household daily expenditure</td>
<td>10321,920</td>
<td>12560,680</td>
<td>9168,350</td>
<td>7438,137</td>
<td>1153,570</td>
<td></td>
</tr>
<tr>
<td>Separate kitchen (dummy, 1= yes)</td>
<td>0.411</td>
<td>0.493</td>
<td>0.421</td>
<td>0.495</td>
<td>-0.010</td>
<td></td>
</tr>
<tr>
<td>Residential house privately owned (dummy, 1= yes)</td>
<td>0.466</td>
<td>0.500</td>
<td>0.515</td>
<td>0.501</td>
<td>-0.049</td>
<td></td>
</tr>
<tr>
<td>Saving account (dummy, 1= yes)</td>
<td>0.462</td>
<td>0.499</td>
<td>0.458</td>
<td>0.499</td>
<td>0.004</td>
<td></td>
</tr>
<tr>
<td><strong>Panel B: Cooking Pattern and Charcoal Use</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of years using charcoal stove</td>
<td>24,007</td>
<td>11,516</td>
<td>22,987</td>
<td>10,814</td>
<td>1,020</td>
<td></td>
</tr>
<tr>
<td>Head decides on acquisition of stove (dummy, 1= yes)</td>
<td>0.466</td>
<td>0.500</td>
<td>0.421</td>
<td>0.495</td>
<td>0.045</td>
<td></td>
</tr>
<tr>
<td>Distance to nearest charcoal market (in minutes)</td>
<td>4,945</td>
<td>4,060</td>
<td>4,236</td>
<td>4,752</td>
<td>0.710</td>
<td></td>
</tr>
<tr>
<td>Number of meals cooked last week</td>
<td>19,301</td>
<td>3,303</td>
<td>19,121</td>
<td>3,492</td>
<td>0.180</td>
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</tr>
<tr>
<td>Number of meals cooked using charcoal</td>
<td>16,356</td>
<td>4,596</td>
<td>16,364</td>
<td>4,654</td>
<td>-0.007</td>
<td></td>
</tr>
<tr>
<td>Rice, main staple for the household (dummy, 1= yes)</td>
<td>0.497</td>
<td>0.501</td>
<td>0.488</td>
<td>0.501</td>
<td>0.008</td>
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</tr>
<tr>
<td>Beans, main sauce (dummy, 1= yes)</td>
<td>0.476</td>
<td>0.500</td>
<td>0.522</td>
<td>0.500</td>
<td>-0.046</td>
<td></td>
</tr>
<tr>
<td>Amount of charcoal used last week (in Kg.)</td>
<td>19,193</td>
<td>8,781</td>
<td>19,734</td>
<td>11,735</td>
<td>-0.541</td>
<td></td>
</tr>
<tr>
<td>Total expenditure on charcoal last week (in TZS)</td>
<td>11072,760</td>
<td>4821,808</td>
<td>11498,890</td>
<td>7474,942</td>
<td>-426,130</td>
<td></td>
</tr>
<tr>
<td><strong>Panel C: Demand for LPG stoves</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Household knows about LPG stoves (dummy, 1= yes)</td>
<td>0.983</td>
<td>0.130</td>
<td>0.983</td>
<td>0.129</td>
<td>0.000</td>
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</tr>
<tr>
<td>Knows someone using LPG stove (dummy, 1= yes)</td>
<td>0.818</td>
<td>0.386</td>
<td>0.791</td>
<td>0.407</td>
<td>0.027</td>
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</tr>
<tr>
<td>High start up cost of LPG (dummy, 1= yes)</td>
<td>0.921</td>
<td>0.270</td>
<td>0.936</td>
<td>0.245</td>
<td>-0.015</td>
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</tr>
<tr>
<td>High cost of refilling (dummy, 1= yes)</td>
<td>0.719</td>
<td>0.450</td>
<td>0.700</td>
<td>0.459</td>
<td>0.019</td>
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</tr>
<tr>
<td>Difference in taste of food (dummy, 1= yes)</td>
<td>0.031</td>
<td>0.173</td>
<td>0.020</td>
<td>0.141</td>
<td>0.011</td>
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</tr>
<tr>
<td>Distance to the nearest gas dealer</td>
<td>17,836</td>
<td>14,423</td>
<td>18,022</td>
<td>14,081</td>
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<td>Observations</td>
<td>296</td>
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<td>297</td>
<td></td>
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Notes: ***p < 0.01, ** p < 0.05, *p < 0.1.
Table 4: Charcoal Consumption at Baseline and Follow-up, Treatment and Control Group

<table>
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<tr>
<th></th>
<th>Baseline</th>
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<th>Follow-up</th>
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<th>Obs.</th>
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<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
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</tr>
<tr>
<td><strong>Panel A: Amount of Charcoal in KG.</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treated</td>
<td>19.24</td>
<td>9.18</td>
<td>13.52</td>
<td>17.33</td>
<td>-5.72</td>
<td>1.14</td>
<td>296</td>
</tr>
<tr>
<td>Control</td>
<td>19.40</td>
<td>11.70</td>
<td>19.71</td>
<td>10.02</td>
<td>-0.31</td>
<td>0.87</td>
<td>314</td>
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<tr>
<td>Diff</td>
<td>-0.16</td>
<td>0.85</td>
<td>-6.19***</td>
<td>1.14</td>
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<td></td>
<td></td>
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<tr>
<td><strong>Panel B: Value of Charcoal in TZS</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Treated</td>
<td>11112.86</td>
<td>5163.02</td>
<td>8354.46</td>
<td>6541.76</td>
<td>2758.41</td>
<td>483.57</td>
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<tr>
<td>Control</td>
<td>11279.09</td>
<td>7455.48</td>
<td>12125.99</td>
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<td>-846.90</td>
<td>584.59</td>
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<tr>
<td>Diff</td>
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<td>-3772***</td>
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Notes: ***p < 0.01, **p < 0.05, *p < 0.1.

Table 5: Impact of LPG Stoves on Charcoal Consumption

<table>
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<th>[1]</th>
<th>[2]</th>
<th>[3]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[Charcoal/Week - kg (log)]</td>
<td>[Charcoal/Week - kg (log)]</td>
<td>[Charcoal/Week - kg (log)]</td>
</tr>
<tr>
<td>Treatment</td>
<td>-0.475***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0881)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Credit Treatment</td>
<td>-0.414***</td>
<td>-0.384***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0938)</td>
<td>(0.0783)</td>
<td></td>
</tr>
<tr>
<td>Subsidy Treatment</td>
<td>-0.541***</td>
<td>-0.527***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.134)</td>
<td>(0.126)</td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>2.899***</td>
<td>2.899***</td>
<td>2.784***</td>
</tr>
<tr>
<td></td>
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<td>(0.0369)</td>
<td>(0.248)</td>
</tr>
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<td>Controls</td>
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<td>No</td>
<td>Yes</td>
</tr>
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<td>593</td>
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<tr>
<td>R-squared</td>
<td>0.091</td>
<td>0.094</td>
<td>0.122</td>
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Notes: ***p < 0.01, **p < 0.05, *p < 0.1.
Table 6: LPG Stove Use: OLS Regression Results

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<thead>
<tr>
<th></th>
<th>LPG Use</th>
<th>LPG Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Credit Treatment</td>
<td>-1.126</td>
<td>-1.159</td>
</tr>
<tr>
<td></td>
<td>(1.205)</td>
<td>(1.105)</td>
</tr>
<tr>
<td>Age</td>
<td>0.0268</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0486)</td>
<td></td>
</tr>
<tr>
<td>Household size</td>
<td>0.315</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.306)</td>
<td></td>
</tr>
<tr>
<td>Years of schooling</td>
<td>0.445*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.219)</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>-0.837</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.686)</td>
<td></td>
</tr>
<tr>
<td>Separate kitchen (dummy, 1= yes)</td>
<td>-1.135</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.991)</td>
<td></td>
</tr>
<tr>
<td>Residential house privately owned (dummy, 1= yes)</td>
<td>-1.526</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.072)</td>
<td></td>
</tr>
<tr>
<td>Number of years using charcoal stove</td>
<td>-0.0414</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0375)</td>
<td></td>
</tr>
<tr>
<td>Head decides on acquisition of stove (dummy, 1= yes)</td>
<td>1.295</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.195)</td>
<td></td>
</tr>
<tr>
<td>Number of meals cooked last week</td>
<td>-0.0388</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.176)</td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>12.03***</td>
<td>8.446*</td>
</tr>
<tr>
<td></td>
<td>(0.669)</td>
<td>(3.952)</td>
</tr>
<tr>
<td>Observations</td>
<td>296</td>
<td>296</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.005</td>
<td>0.059</td>
</tr>
</tbody>
</table>

Notes: Standard errors clustered at the street level, ***p < 0.01, **p < 0.05, *p < 0.1.
Table 7: Satisfaction With LPG Stoves: Probit Regression Results

<table>
<thead>
<tr>
<th></th>
<th>Quality</th>
<th>Functioning</th>
<th>Food Taste</th>
<th>Cost</th>
<th>Convenience</th>
</tr>
</thead>
<tbody>
<tr>
<td>Credit Treatment</td>
<td>-0.273</td>
<td>-0.309</td>
<td>-0.142</td>
<td>-0.237</td>
<td>-0.250</td>
</tr>
<tr>
<td></td>
<td>(0.248)</td>
<td>(0.228)</td>
<td>(0.212)</td>
<td>(0.212)</td>
<td>(0.217)</td>
</tr>
<tr>
<td>Age</td>
<td>-0.00510</td>
<td>-0.000919</td>
<td>0.000793</td>
<td>0.00441</td>
<td>-0.00177</td>
</tr>
<tr>
<td></td>
<td>(0.00755)</td>
<td>(0.00751)</td>
<td>(0.00967)</td>
<td>(0.00683)</td>
<td>(0.00808)</td>
</tr>
<tr>
<td>Household size</td>
<td>0.0795*</td>
<td>0.0448</td>
<td>0.0839*</td>
<td>0.0416</td>
<td>0.0878***</td>
</tr>
<tr>
<td></td>
<td>(0.0408)</td>
<td>(0.0379)</td>
<td>(0.0476)</td>
<td>(0.0368)</td>
<td>(0.0290)</td>
</tr>
<tr>
<td>Years of schooling</td>
<td>0.0756**</td>
<td>0.0800**</td>
<td>0.0998***</td>
<td>0.0718*</td>
<td>0.0789**</td>
</tr>
<tr>
<td></td>
<td>(0.0327)</td>
<td>(0.0318)</td>
<td>(0.0327)</td>
<td>(0.0416)</td>
<td>(0.0322)</td>
</tr>
<tr>
<td>Male</td>
<td>-0.366*</td>
<td>-0.374</td>
<td>-0.267</td>
<td>-0.407*</td>
<td>-0.435*</td>
</tr>
<tr>
<td></td>
<td>(0.205)</td>
<td>(0.256)</td>
<td>(0.262)</td>
<td>(0.245)</td>
<td>(0.247)</td>
</tr>
<tr>
<td>Separate kitchen</td>
<td>-0.0582</td>
<td>-0.0119</td>
<td>-0.00106</td>
<td>0.107</td>
<td>0.0527</td>
</tr>
<tr>
<td></td>
<td>(0.222)</td>
<td>(0.234)</td>
<td>(0.187)</td>
<td>(0.229)</td>
<td>(0.221)</td>
</tr>
<tr>
<td>Residential house privately owned</td>
<td>-0.266</td>
<td>-0.243</td>
<td>-0.196</td>
<td>-0.286</td>
<td>-0.223</td>
</tr>
<tr>
<td></td>
<td>(0.183)</td>
<td>(0.220)</td>
<td>(0.186)</td>
<td>(0.189)</td>
<td>(0.190)</td>
</tr>
<tr>
<td>Number of years using charcoal stove</td>
<td>0.00779</td>
<td>-0.000186</td>
<td>-0.00815</td>
<td>-0.000188</td>
<td>-0.00395</td>
</tr>
<tr>
<td></td>
<td>(0.00818)</td>
<td>(0.00807)</td>
<td>(0.00803)</td>
<td>(0.00808)</td>
<td>(0.00809)</td>
</tr>
<tr>
<td>Head decides on acquisition of stove</td>
<td>0.0683</td>
<td>0.0123</td>
<td>0.119</td>
<td>-0.0531</td>
<td>0.0111</td>
</tr>
<tr>
<td></td>
<td>(0.286)</td>
<td>(0.281)</td>
<td>(0.228)</td>
<td>(0.261)</td>
<td>(0.265)</td>
</tr>
<tr>
<td>Number of meals cooked last week</td>
<td>-0.00608</td>
<td>-0.00579</td>
<td>0.000139</td>
<td>-0.00231</td>
<td>0.0111</td>
</tr>
<tr>
<td></td>
<td>(0.0267)</td>
<td>(0.0300)</td>
<td>(0.0248)</td>
<td>(0.0339)</td>
<td>(0.0315)</td>
</tr>
<tr>
<td>Intercept</td>
<td>0.542</td>
<td>0.689</td>
<td>-0.138</td>
<td>0.351</td>
<td>0.264</td>
</tr>
<tr>
<td></td>
<td>(0.671)</td>
<td>(0.716)</td>
<td>(0.638)</td>
<td>(0.833)</td>
<td>(0.823)</td>
</tr>
<tr>
<td>Observations</td>
<td>296</td>
<td>296</td>
<td>296</td>
<td>296</td>
<td>296</td>
</tr>
<tr>
<td>Pseudo $R^2$ - squared</td>
<td>0.065</td>
<td>0.061</td>
<td>0.066</td>
<td>0.049</td>
<td>0.065</td>
</tr>
</tbody>
</table>

Notes: Robustness standard errors in parentheses, **p < 0.01, * p < 0.05, *p < 0.1.

Table A1 Reasons for not using LPG Stoves

<table>
<thead>
<tr>
<th></th>
<th>No.</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas run out</td>
<td>5</td>
<td>0.07</td>
</tr>
<tr>
<td>Stove/parts mulfunction</td>
<td>3</td>
<td>0.04</td>
</tr>
<tr>
<td>Type of food cooked</td>
<td>2</td>
<td>0.03</td>
</tr>
<tr>
<td>Not confident on how to operate the stove</td>
<td>4</td>
<td>0.05</td>
</tr>
<tr>
<td>Non of the above</td>
<td>60</td>
<td>0.81</td>
</tr>
<tr>
<td>Observations</td>
<td>74</td>
<td>1.00</td>
</tr>
</tbody>
</table>
Figure 1: Map of Dar Es Salaam City Council Showing Municipalities
Figure A2

Distribution of households by the number of times LPG stove has been used over the past week
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