Working paper

International Growth Centre

Liquidity constraint, LPG stoves, and charcoal consumption

A randomised controlled trial in Tanzania

Yonas Alem
Remidius D. Ruhinduka
Peter Berck

July 2017

When citing this paper, please use the title and the following reference number:
E-89410-TZA-1

DIRECTED BY
LSE
UNIVERSITY OF OXFORD

FUNDED BY
UKaid
from the British people

Liquidity Constraint, LPG Stoves and Charcoal Consumption: A Randomized Controlled Trial in Tanzania*

Yonas Alem
University of Gothenburg †

Remidius D. Ruhinduka
University of Dar es Salaam ‡

Peter Berck
UC Berkeley §

July 27, 2017

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 and measure the impact on charcoal consumption both 4 months and 15 months after the stoves have been distributed. We show that, relative to households in the control group, adoption of LPG stoves reduced charcoal consumption by about 27% in the treated group 15 months after the intervention. However, providing subsidies for stove purchases resulted in a much larger reduction in charcoal use (32%) than did providing access to credit (24%). 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 Randall Bluffstone for helpful input in the research design, Håkan Eggert, Andrew Foster, Gunnar Köhlin, Subhrendu Pattanayak, the energy research team of the International Growth Center (IGC), based at the London School of Economics (LSE), seminar participants at the University of California Berkeley, University of California Davis, University of Gothenburg, Peking University, Renmin University of China, the Indian Statistical Institute, the Reign West Phelia Economic Research Center and participants at the 8^{th} (EfD) Environment for Development network annual meeting for useful comments and suggestions on earlier versions of the paper. The randomised controlled trial in this paper was generously funded by 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. Part of this research was done while both Alem and Ruhinduka were visiting scholars at Brown University. All errors and omissions are of the authors.

†Corresponding Author: Department of Economics, University of Gothenburg, e-mail: yonas.alem@economics.gu.se.

‡Department of Economics, University of Dar es Salaam, e-mail: rremidius@yahoo.com.

§Department of Agricultural and Resource Economics, UC Berkeley, e-mail: peter.berck@berkeley.edu.

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 on which 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 Dar es Salaam city alone consumes 500,000 tonnes of charcoal, half of the total annual charcoal consumption of the country (World Bank, 2009). On the other hand, many SSA countries - including Tanzania - have been experiencing economic growth which resulted in increased income and living standard in urban areas in the past decade (AfDB, 2014). The fact that charcoal consumption has been increasing with increasing income is contrary to the predictions of the "energy ladder theory", 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 induce households in urban areas of Africa to shift from biomass fuel (charcoal) to modern fuel, Liquified Petrolium 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 irreplaceble 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 causes about 2 million premature deaths per year (WHO, 2009). Recent studies also documented that biomass fuel, 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 for 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; Miller and Mobarak, 2013; Hanna et al. 2016) have 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 point out the 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 relax liquidity constraints can induce

them switch to modern cookstoves, or whether dependence on charcoal for cooking is driven by cultural factors that cannot 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 high-cost cooking appliances (LPG stoves) and on charcoal consumption. In order to shed light on our hypothesis, 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 through 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 conduct a randomized controlled trial to understand the factors that drive switching to cleaner energy sources and the corresponding reduction in charcoal consumption.

We take advantage of our randomised design to estimate the impact of adoption of LPG stoves through subsidy and on credit schemes on charcoal consumption. In order to study the effects, we conduct comprehensive baseline, midline (four months after the stoves have been distributed), and at endline (15 months after the stoves have been distributed). Our results indicate that LPG stove adoption overall resulted in a significant reduction in total charcoal use by the treatment group. Specifically, intent to treat (ITT) estimates indicate that households in treated communities consumed 31.8 percent less charcoal compared to the control group four months after the program was rolled out, and 27.4 percent less charcoal 15 months later. This amounted to a reduction in charcoal consumption from about 19 kg/week at the baseline to about 16 kg/week during the midline follow-up and 15.8 kg/week during the endline follow-up. We find much larger (34.5% and 31.5%) reductions in charcoal consumption during the midline and endline follow-ups respectively by households who adopted LPG stoves through subsidy compared to those who acquired them through credit (29.1% and 23.6% reductions at midline and endline follow-ups respectively).

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).[1] Our findings have significant implications for policies that aim at promoting transition of households to cleaner energy sources, and saving the remaining forest resources of the continent. Although LPG is fossil fuel, it is much more efficient and emits way less CO2 and zero black carbon compared to charcoal.[2] Consequently, LPG can play a significant role in energy transition in developing countries. Given that reducing the startup cost of LGP 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

[1]The 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 the harvested wood was burned to meet cooking energy needs.

[2]IPCC (2006) assigned a global warming potential (GWP) factor zero to LPG, i.e., it is not a greenhouse gas.

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 district both in terms of geographical size and population.[3] 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 (NBS, 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 alone consumes half of this amount (World Bank, 2009).

Tanzania has recently discovered huge reserves of natural gas, which is expected to play a significant role in the country's economy by transforming the energy sector and boosting the gross domestic product.[4] 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 for poor households. Findings from the baseline survey, which we present in the next sections support this skepticism. Almost all households we surveyed (99 percent) stated a high level of awareness about LPG stoves and their benefits but felt constrained not to adopt, mainly because of the high initial cost.[5]

Our study is conducted at an important time to provide useful and policy relevant evidence on the constraints that households face in adopting modern cookstoves and switching away from charcoal, as well as the roles public policy can play in tackling these constraints.. 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.

[3] See figure A1 in the appendix for map of Dar es Salaam.

[4] http://allafrica.com/stories/201504030134.html.

[5] Currently, less than 4 percent of households in urban Tanzania own modern cooking stoves such as electric or gas stoves (NBS 2012).

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 the residences of a majority of the low income urban households in Dar es Salaam and share similar socioeconomic characteristics but are located at a distance 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 the quality of roads, footpaths, drainage, sanitation, solid waste, street lighting, 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. We then selected the top four streets by 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 a roster of eligible households in their streets, from which we randomly selected a total of 722 households to participate in the baseline survey. Eligibility criteria required that the selected households never owned/used an LPG stove and used charcoal (but not kerosene) as their main source of cooking energy.[6]

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 an average of about 3000 households in each sampled street. Street-level randomization also makes implementation of the program relatively easier as it seems fair from households' point of view, and is politically acceptable to the 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 with the stoves by households under the two treatments. We thus randomly assigned five streets into the credit treatment, four 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.

[6]The proportion of households that use kerosene gas in Dar es Salaam is only about 7.8% (NBS 2012).

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 of 40 urban households during October-November 2014. The aim of this survey was to document both qualitative and quantitative background information about 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 regarding knowledge and willingness to adopt LPG stoves, either on credit or through subsidy programs. We also found that high start-up cost seemed to be the main factor that hindered households from acquiring the stove.

We conducted a comprehensive baseline survey during March-April 2015, covering all 722 sampled households in the 16 sub-wards. In the baseline we included questions on demographic and other socioeconomic 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 through a 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 was one of the households randomly selected to receive an LPG stove through a 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 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 a good reputation and credibility in disbursement and handling of different types of loans, including micro-credit to finance the purchase of home appliances.[7] 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 physical asset other than the stove itself as collateral. In addition, all credit treatment households

[7]See "http://watsaccos.co.tz" for more information about WAT-SACCO.

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 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 the LPG stove in its full package. The training included instructions on how to safely use, clean, maintain and re-fill the LPG stoves once the startup gas runs out.[8] 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 inconvenience, 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 or every 30th day of the month, depending on the treatment type. The complete loan repayment period was set to be six 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 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 were distributed - to collect information on key outcome variables of interest, including charcoal consumption, LPG stove use, compliance with treatment, and satisfaction with the stoves.[9]

Finally, in order to assess the longer term impact of our interventions, we conducted a comprehensive end-line follow up survey during July-August, 2016, i.e., 15 months after the interventions. We documented detailed information on household and community characteristics, cookstove use, energy use and consumption, cooking habits, and LPG stove use and satisfaction.

3 Descriptive Stats, Randomization Checks and Attrition

Table 1 presents descriptive statistics of key household socioeconomic 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, which is slightly higher than the standard primary school level in Tanzania (7 years). About half of the sample households live in privately owned households, but only 41% have access to a separate private kitchen, the remainder either cooking in their corri-

[8] See figure A2 in the appendix for pictures taken during training and home visits.

[9] We initially planned to conduct the mid-line survey six months after the stoves were 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.

dors 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).[10] We notice, however 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 of 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 fairly strong intra-household bargaining power when it comes to acquisition of kitchen appliances. The type of meals cooked by the household could influence the amount and type of fuel used due to the cooking time and taste of food. During the fact finding survey, a few respondents argued that, while rice tastes better when cooked on a charcoal stove, it takes significantly longer 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 within their close network who uses the stove.. However, 93 percent of the the sample households reported the high startup cost of the stove package as the main constraint to their adoption. 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.

[10] At the time of the baseline survey, 1 USD = 1800 TZS.

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 because the proportion of households who own a saving account in the control group is about 9 percentage points higher than in the credit treatment group.

Table 2 about here

In order to investigate whether the decision by some of the treatment households not to buy the LPG stoves 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 bias in our sample.

Table 3 about here

During the midline survey conducted about 4 months after the intervention, the proportion of households we could not track was only 3%. However, the proportion increased to about 27% during the endline survey which was conducted 15 months after the intervention. It is common to encounter a larger rate of attrition in urban areas than in rural areas of developing countries (Bandiera et al. 2015, Friedman et al. 2011, Duflo et al. 2014). As shown in Table 1, about half of our sample of households reside in rented residential places. By the time of the endline survey, a number of households had moved to rented apartments in other parts of the city. While the survey team managed to track some of those who moved to new locations using their cell phone numbers, others could not be traced and thus we could not document endline information for these households.

In order to check if attrition in our sample has been systematic, we run a probit regression for the correlates of attrition and report the results in Table 4. The dependent variable is a dummy equal to one if the household attrits by endline. Column 1 controls for being treated (LPG aquisition either on credit or through subsidy). Column 2 differentiates the correlates of attrition by the type of intervention. Column 3 controls for other socio-economic characteristics in addition to the type of treatment. Results in all columns suggest that none of our interventions are statistically significant in predicting attrition. Column 3 however shows households living in own residential property are less likely to attrit and the correlation is statistically significant at the one percent level. This is consistent with our actual observation during the endline survey. We also note that households with educated heads are less likely to attrit. In the results section, we compute treatment effects, which control for the possible impacts of attrition.

Table 4 about here

4 Results

4.1 Specification

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. As participation in our interventions (both credit and subsidy) are voluntary, not all households who have been assigned to the interventions take-up the offer. Consequently, we focus on intent-to-treat (ITT) impacts. Given random assignment of sub-wards to treatment, we can estimate the ITT impact of the LPG credit and subsidy programs using the following OLS specifications.

$$y_{ijt} = \alpha + \gamma treat_j + \beta X_{ij0} + \varepsilon_{ijt} \tag{1}$$

and

$$y_{ijt} = \alpha + \eta credit_j + \theta subsidy_j + \beta X_{ij0} + \varepsilon_{ijt} \tag{2}$$

where y_{ijt} is our key outcome variable of interest, charcoal consumption by household i in sub-ward j at 4 months follow-up ($t = 1$) and 15 months follow-up ($t = 2$), $treat$ is a binary indicator for either credit or subsidy treatment, $credit$ and $subsidy$ refer to binary indicators of treatment type, X_{ij0} are control variables at the baseline, ε_{ijt} is a random error term that we allow to be clustered by sub-ward j, and γ, η and θ are the coefficients of interest, measuring the ITT impact of our credit and subsidy interventions.

In order to minimise measurement error in the outcome variable of interest during all the three surveys, households were asked to keep 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.

4.2 Charcoal Consumption

We begin with results from the simple mean comparison of weekly charcoal consumption between the treatment and control groups during the baseline, mid-line (4 months after the interventions) and endline (15 months after the interventions), as reported in Table 5. Panel A presents the results for the quantity of charcoal consumed. While the treatment and control groups reported similar amounts of charcoal consumption per week during the baseline (18.9 kg and 19.78 kg respectively), treated households consumed 3.85 kg less in a week compared to the control households during the midline follow-up survey, and 3.79 kg less in a week during the endline follow-up survey. Both these effects translate into a large reduction in charcoal use which is statistically significant at the one percent level. In panel B, we present the monetary value of the reduction in charcoal due to adoption of LPG stoves. The results reveal that compared to the control group, adoption of

LPG stoves reduced the amount of weekly charcoal expenditure for the treatment group by about 2,900TZS (USD 1.61) at midline follow-up and to about 2,300 TZS (USD 1.28) at the endline follow-up.

Table 5 about here

Table 6 provides formal empirical estimation of intent to treat (ITT) from an OLS model. Column (1) presents the results for the impact of adoption of LPG, regardless of the treatment type at the midline. In columns (2) and (3), we extend the analysis by controlling for the type of treatment (subsidy and credit), and for controls. This is very important from a public policy point of view given the ongoing debate about the idea 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 6 suggests that compared to the treatment group, LPG adoption reduced charcoal consumption by about 31.8 percent per week four months after the interventions. When we assess the impact by the treatment type, results in column 2 suggest a relatively larger impact (34.5 percent) for the stoves adopted through a subsidy compared to the control group than those purchased on credit (29.1 percent). The results remain robust even after controlling for other covariates (column 3).

Table 6 about here

In columns (4) - (6), we investigate the impact of adoption of LPG stoves at endline - 15 months after the stoves have been distributed. This is important given the recent finding that after stoves have been adopted, households might not continue using them for several reasons (Hanna et al. 2016). Results remain quite robust 15 months after the intervention. On average, LPG adoption reduced charcoal consumption by 27.4 percent (column 4), acquiring the stoves through subsidy resulted in 31.5 percent reduction in charcoal use, and acquiring them on credit led to a 23.6 percent reduction in charcoal use column (5). Controlling for household characteristics in column (6) reduces the treatment effects slightly, but the effects remain robust.

Both at the midline and at the endline follow-ups, we document difference in the impact of LPG stoves on charcoal consumption between the credit and subsidy treatments, which we believe can be explained by several factors. The main reason for such a difference at the midline 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 through a subsidy and who actually have full ownership. This could be more pronounced by the fact that the stoves themselves are collateral for the credit. In addition, it is plausible to expect that households in the credit treatment had to pay the full cost of the stoves, while those in the subsidy treatment acquired them at a much lower subsidized price. Consequently, subsidy households might have refilled gas more frequently and reduced charcoal consumption. However, the difference seems to have persisted even at the endline follow-up, i.e., 15 months after the stoves have been distributed.

4.3 Satisfaction with 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) suggests that households may continue to use the charcoal stove in combination with the LPG stove, a phenomenon known as "fuel stacking". During the midline follow-up survey, almost 25 percent of the treated households (i.e., 74 households) reported not to have used the LPG stove over the past one week. Table A3 in the Appendix shows the distribution of reasons for not using the LPG stoves during the midline survey among those who received the stoves.

In Table 7, we explore if stove use and intensity are correlated with the type of treatment assigned to households both at the midline and endline. Midline results reported in column [1] suggest that the number of times the stove is put to use is not correlated with the treatment category in a statistically significant manner. These results are robust to controlling for other covariates. However, results show that incomplete knowledge on how to operate an LPG gas stove and gas run out are negatively correlated with stove use. This is expected given the fact that the treated households only had about four months of experience in using the stoves by the time of the midline follow-up survey. Fifteen months after the intervention, i.e., during the endline, however, incomplete knowledge on LPG stove use is not correlated with stove use any more. This most likely suggests the presence of learning-by-doing in stove use. During the endline, we observe that gas run out remained to be an important variable in explaining stove use. But we also find education (years of schooling) to be positively correlated with the intensity of LPG stove use. Results in column [4] also suggest that household size is weakly positively correlated with intensity of LPG stove use, while the number of years a household used charcoal for cooking is weakly negatively correlated with LPG stove use.

Table 7 about here

We finally explore the extent to which 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 a high acceptance rate by the 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 8. Two variables appear to be consistently important correlates of satisfaction with LPG stoves. These are household size and years of schooling. Households headed by educated individuals tend to be satisfied with all aspects of the LPG stoves. Larger households tend to be satisfied with all aspect of the stove except with functioning. We do not, however, find any evidence suggesting satisfaction with stove attributes is correlated with the type of treatment, as indicated by the coefficient of the

credit treatment variable, which is statistically insignificant.

Table 8 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 results 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 this hypothesis, we collaborated with one of Tanzania's largest micro-finance institutions, WAT-SACOS, and implemented an LPG gas stove program in a randomised controlled trial setup. The program involved provision of a durable and high-quality two-burner LPG stove package through a subsidy and on 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 on adoption of modern cooking appliances that have a high-start up cost and the corresponding impact on charcoal consumption..

The LPG stoves we offered had a high uptake rate by urban households in Tanzania, with 70 percent adoption by those who were randomly assigned to the treatments. Our results indicate that, overall, adoption of LPG stoves reduced charcoal consumption by about 27.4 percent per week compared to the control group 15 months after the stoves have been distributed. When we assess the impact by the treatment type, estimates suggest that, compared to the control group, those who adopted the stoves through a subsidised price reduced charcoal consumption by 31.5 percent while those who adopted the stoves on credit reduced charcoal consumption by 23.6 percent. These results are robust to controlling for 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 difference in stove use and impact on charcoal consumption during the midline survey was most likely driven by the fact that the survey took place a couple of months before the full credit amount had been paid out by households, who probably did not feel complete ownership of the LPG stoves. Interestingly however, the difference remained significant between the two groups during the endline survey which took place 15 months after the stoves have been distributed.

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 is likely to provide substantial 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 relatively environmentally-friendly energy. In view of this, simple policy interventions such as reducing the import duty

on LPG stoves could increase adoption and use of LPG stoves and consequently reduce charcoal consumption. This is the main message of our study, which could be useful to policymakers, donors, and other stakeholders who are interested in saving the remaining forest resources of Africa.

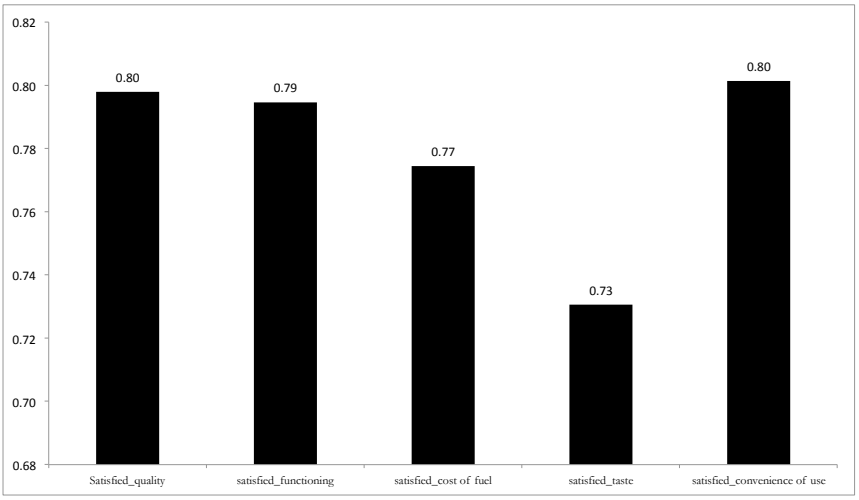
References

- African Development Bank (AfDB) (2014). African Development Report: Regional Integration for Inclusive Growth. http://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/ADR14-ENGLISH-web.pdf
- Alem, Y., Hassen, S., and Köhlin, G. 2014. "Adoption and Disadoption of Electric Cookstoves in Urban Ethiopia: Evidence from Panel Data." Resource and Energy Economics 38: 110-124.
- Alem,Y., Eggert, H., Kocher, M., and Ruhunduka, R. 2015. "Why (field) experiments on unethical behavior are important: Comparing stated and revealed behavior." Unpublished.
- Allen, J.C., Barnes, D.F. 1985. "The causes of deforestation in developing countries." Annals of the Association of American Geographers 75 (2): 163?184.
- Angelsen, A., Brockhaus, M., Kanninen, M., Sills, E., Sunderlin, W. D. and Wertz-Kanounnikoff, S., eds,. 2009. Realising REDD+: National strategy and policy options. IFOR, Bogor,Indonesia. http://www.cifor.org/publications/pdf-files/Books/BAngelsen0902.pdf
- Bandiera, O., Buehren, N., Burgess, R., Goldstein, M., Gulesci, S., Rasul, I., and Sulaiman, S. (2015), "Women's Empowerment in Action: Evidence from a Randomized Control Trial in Africa", Employment Policy Department Employment Working Paper, No. 187, ILO,Geneva.
- Baron, R.E., Montgomery, D.W., and Tuladhar, S.D. 2009. "An Analysis of Black Carbon Mitigation as a Response to Climate Change" http://www.copenhagenconsensus.com/sites/default/files/ap-black-carbon-baron-montgomery-tuladhar-v.4.0.pdf
- Bertrand, M and Mullainathan. S. 2001. "Do people mean what they say? Implications for subjective survey data." Economics and Social Behavior 91(2):67-72
- Campbell, B. M., Angelsen, A., Cunningham, A., Katerere, Y., Sitoe, A., and Wunder, S. 2007. "Miombo woodlands, opportunities and barriers to sustainable forest management" CIFOR, Bogor, Indonesia. http://www.cifor.cgiar. org/miombo/docs/Campbell- Barriers and Opportunities. pdf (4th November 2008).
- Cohen, J. and Dupas, P. 2010. "Free distribution or cost-sharing? Evidence from a randomized malaria prevention experiment". The Quarterly Journal of Economics 125 (1): 1-45.
- Deaton, A. 1997. The analysis of household surveys: A microeconomic approach to development policy. Baltimore: Johns Hopkins University Press.
- Duflo, E. Dupas, P. and Kremer, M. (2015) "Education, HIV and Early Fertility: Experimental Evidence from Kenya", American Economic Review, Vol.105(9), pp.2757-97.
- Edwards, J.H.Y., and Langpap, C. 2005. "Startup costs and the decision to switch from firewood to gas fuel." Land Econ 81 (4): 570-586.

- Friedman, W., Kremer, M., Miguel, E., and Thornton, R. (2016), "Education as Liberation?",Economica, Vol.83 (329), pp.1-30
- Grosh, M., and Glewee, P., Eds. 2000. Designing household survey questionnaires for developing countries: Lessons from 15 years of the living standards measurement study. Volume 1. Oxford: Oxford University Press.
- Geist, H.J., and Lambin, E.F. 2002. "Proximate causes and underlying driving forces of tropical deforestation." BioScience 52 (2): 143?150.
- Grieshop, A.P, Marshall, J.D, and Kandlikar, M. 2011. "Health and climate benefits of cookstove replacement options." Energy Policy 39: 7530-7542
- Hanna, R., Duflo, E., Greenstone, M. 2016. "Up in the Smoke: the Influence of Household Behavior on the Long-run Impact of Improved Cookstoves." American Economic Journal: Economic Policy 8(1): 80-114.
- Heltberg, R. 2005. "Factors Determining Household Fuel Choice in Guatemala," Environment and Development Economics 10: 337-61.
- Hoffman, V. 2009. "Intrahousehold Allocation of Free and Purchased Mosquito Nets." American Economic Review: Papers and Proceedings 99 (2): 236-241.
- Hoffman. V. Barrett, C., and Just. D. (2009). "Do Free Goods Stick to Poor Households? Experimental Evidence on Insecticide Treated Bednets". World Development 37 (3): 607-617.
- Hofstad, O., Köhlin, G., and Namaalway, F. 2009. "How Can Emissions From Woodfuel be Reduced?" Realising REDD+: National Strategy and Policy Options (Angelsen, A., Brockhaus, M., Kanninen, M., Sills, E., Sunderlin, W.D, Wertz-Kanounnikoff,S.). Center for International Forestry Research, Bogor, Indonesia, pp. 237-248.
- IPCC (2006). Energy, Guidelines for National GHG Inventories,volume 2, Intergovernmental Panel on Climate Change.
- Köhlin, G., Sills, E.O., Pattanayak, S.K., and Wilfong, C., 2011. "Energy, Gender and Development." World Bank Policy Research Working Paper Series 5800.
- Kandlikar, M., Reynolds, C.C.O., and Grieshop, A.P. 2009. "A Perspective Paper on Black Carbon Mitigation as a Response to Climate Change". Released by the Copenhagen Consensus Center. Retrieved October 27, 2015. http://www.copenhagenconsensus.com/sites/default/files/pp-black-carbon-kandlikar-reynolds-grieshop-v.1.0.pdf.
- Lewis, J.J., and Pattanayak, S.K. 2012. "Who adopts improved fuels and cook stoves? A systematic review." Environmental Health Perspectives 120 (5): 637-645.
- Miller, G., and A. Mushfiq, M. 2014. "Learning about new technologies through social networks: Experimental evidence on non-traditional stoves in Bangladesh." Marketing Science 34(4): 480-499.

- National Bureau of Statistics (NBS). 2012. Tanzania National Panel Survey Report - Wave 2, 2010-2011. http://siteresources.worldbank.org/INTSURAGRI/Resources/7420178-1294154345427/NPS-Report-2010-2011.pdf
- Masera, O., B. Saatkamp, and D. Kammen. 2000. "From Linear Fuel Switching to Multiple Cooking Strategies: A Critique and Alternative to the Energy Ladder Model," World Development 28(12): 2083-2103.
- Mercer, B., Finighan, J., Sembres, T. and Schaefer, J. 2011. Protecting and restoring forest carbon in tropical Africa: A guide for donors and funders. Forests Philanthropy Action Network. http://files.forestsnetwork.org/FPAN+Africa+report+chapter+1+HR.pdf
- Sagar, A.D., and Kartha, S. 2007. "Bioenergy and sustainable development?". Annual Review of Environment and Resources 32(1):131 167.
- Tone, S., Diaz, E., Pope, D., Lie, L.T., Diaz, A., McCracken, J.P., Bakke, P., Arana, B. Smith, K.R., and Bruce,N. 2009. "Effect of Reducing Indoor Air Pollution on Women's Respiratory Symptoms and Lung Function: RESPIRE Guatemala Randomized Trial." American Journal of Epidemiology 170(2): 211-220.
- World Bank. 2009. "Environmental crisis or sustainable development opportunity? Transforming the charcoal sector in Tanzania." A Policy Note. The World Bank. Washington DC.
- WHO, (World Health Organization). 2009. Global Health Risks: Mortality and Burden of Disease Attributable to Major Risks. http://www.who.int/healthinfo/global-burden-disease/GlobalHealthRisks-report-full.pdf
- United Republic of Tanzania (URT). 2004. "CITY PROFILE for Dar Es Salaam. www.dcc.go.tz.
- United Republic of Tanzania (URT). 2010. "Dar es Salaam Infrastructure Development Programme." www.dcc.go.tz.

Figure 1: Satisfaction with different features of LPG stoves



1.pdf

Table 1: Descriptive Statistics at Baseline

	Mean	SD
PanelA: Socioeconomic Characteristics		
Age	48,004	13,351
Male	0,670	0,470
Household size	5,768	2,222
Annual income (TZS)	309931,000	256702,700
Years of schooling	7,165	3,076
Muslim (dummy, 1= yes)	0,793	0,405
Has access to main grid electricity in the house (dummy, 1= yes)	0,750	0,433
Average household daily expenditure	9661,586	18043,120
Access to separate kitchen room (dummy, 1= yes)	0,406	0,491
Residential house is privately owned (dummy, 1= yes)	0,505	0,500
At least one member owns a saving account (dummy, 1= yes)	0,373	0,484
Panel B: Cooking Pattern and Charcoal Use		
Number of years using charcoal stove	23,748	11,662
Head decides on acquisition of stove (dummy, 1= yes)	0,469	0,499
Distance to nearest charcoal market (in minutes)	4,349	4,224
Number of meals cooked last week	18,885	3,560
Number of meals cooked last week using charcoal	16,073	4,698
Rice, main staple for the household (dummy, 1= yes)	0,477	0,500
Beans, main sauce (dummy, 1= yes)	0,551	0,498
Amount of charcoal used last week (in Kg.)	18,719	10,049
Total expenditure on charcoal last week (in TZS)	10948,030	6107,990
Panel C: Demand for LPG stoves		
Household knows about LPG stoves (dummy, 1= yes)	0,985	0,123
Knows someone using LPG stove (dummy, 1= yes)	0,803	0,398
High start up cost is main reason for not owning LPG (dummy, 1= yes)	0,934	0,249
Difference in taste of food cooked is main reason for not owning LPG (dummy, 1= yes)	0,024	0,152
Household wishes to own LPG stove in the future (dummy, 1= yes)	0,961	0,193
Maximum willingness to pay for an LPG stove package (TZS)	63419,670	38548,520
Can afford gas refilling cost (dummy, 1= yes)	0,882	0,323
Walking distance to the nearest LPG gas dealer (in minutes)	17,757	14,102
Observations	722	

Table 2: Descriptive Statistics by Treatment Type

	[1 - Credit]		[2 - Subsidy]		[3 - Control]		[Diff. 1 Vs 3]	[Diff. 2 Vs 3]
PanelA: Socioeconomic Characteristics								
Age	47,769	12,718	47,048	11,974	47,451	12,802	0,317	-0,403
Male	0,694	0,462	0,660	0,475	0,717	0,451	-0,023	-0,057
Household size	5,644	2,039	5,799	2,236	5,997	2,258	-0,353	-0,198
Annual income in TZS (log)	12,486	0,729	12,427	0,738	12,496	0,695	-0,010	-0,069
Years of schooling	7,602	3,261	7,565	3,022	7,404	2,711	0,198	0,161
Access to main grid electricity (dummy, 1= yes)	0,745	0,437	0,809	0,394	0,811	0,392	-0,066	-0,003
Average household daily expenditure	8877,315	5968,327	10545,450	13892,930	9168,350	6438,137	-291,035	1377,100
Separate kitchen (dummy, 1= yes)	0,421	0,495	0,368	0,484	0,421	0,495	0,000	-0,052
Residential house privately owned (dummy, 1= yes)	0,472	0,500	0,483	0,501	0,515	0,501	-0,043	-0,032
Saving account (dummy, 1= yes)	0,366	0,483	0,469	0,500	0,458	0,499	-0,092**	0,011
Panel B: Cooking Pattern and Charcoal Use								
Number of years using charcoal stove	23,736	11,169	22,737	10,862	22,987	10,814	0,750	-0,250
Head decides on acquisition of stove (dummy, 1= yes)	0,472	0,500	0,435	0,497	0,421	0,495	0,051	0,015
Distance to nearest charcoal market (in minutes)	4,512	4,125	4,696	3,902	4,236	4,752	0,276	0,460
Number of meals cooked last week	19,222	3,105	19,364	3,344	19,121	3,492	0,101	0,242
Number of meals cooked last week using charcoal	16,759	4,136	16,292	4,892	16,364	4,654	0,396	-0,072
Rice, main staple for the household (dummy, 1= yes)	0,537	0,500	0,502	0,501	0,488	0,501	0,049	0,014
Beans, main sauce (dummy, 1= yes)	0,560	0,498	0,488	0,501	0,522	0,500	0,038	-0,034
Amount of charcoal used last week (in Kg.)	19,088	8,942	18,482	9,043	19,734	11,735	-0,646	-1,252
Total expenditure on charcoal last week (in TZS)	11137,440	5191,617	10804,530	4921,571	11498,890	7474,942	-361,450	-694,360
Panel C: Demand for LPG stoves								
Household knows about LPG stoves (dummy, 1= yes)	0,981	0,135	0,990	0,098	0,983	0,129	-0,002	0,007
Knows someone using LPG stove (dummy, 1= yes)	0,819	0,386	0,804	0,398	0,791	0,407	0,028	0,013
High start-up cost of LPG (dummy, 1= yes)	0,949	0,220	0,914	0,281	0,936	0,245	0,013	-0,022
Difference in taste of food (dummy, 1= yes)	0,037	0,189	0,014	0,119	0,020	0,141	0,017	-0,006
Max. willingness to pay for an LPG stove (TZS)	64199,070	37458,220	67263,160	36888,770	60148,150	40281,420	4050,920	7115,010
Can afford gas refilling cost (dummy, 1= yes)	0,889	0,315	0,904	0,295	0,862	0,346	0,027	0,042
Distance to the nearest LPG gas dealer (in minutes)	18,951	15,113	16,145	12,919	18,022	14,081	0,930	-1,876
Observations	216		209		297			

Notes: $***p < 0.01, **p < 0.05, *p < 0.1$.

Table 3: Descriptive Statistics by Treatment Type: Accounting for Uptake

	[Treatment]		[Control]		[Diff.]
	Coeff.	SE	Coeff.	SE	Coeff.
Panel A: Socioeconomic Characteristics Age	47,236	12,183	47,505	12,812	-0,269
Male	0,661	0,474	0,721	0,449	-0,060
Household size	5,712	2,173	5,997	2,258	-0,284
Annual income in TZS (log)	12,494	0,733	12,495	0,696	0,000
Years of schooling	7,642	3,127	7,404	2,711	0,238
Average household daily expenditure	10321,920	12560,680	9168,350	6438,137	1153,570
Separate kitchen (dummy, 1= yes)	0,411	0,493	0,421	0,495	-0,010
Residential house privately owned (dummy, 1= yes)	0,466	0,500	0,515	0,501	-0,049
Saving account (dummy, 1= yes)	0,462	0,499	0,458	0,499	0,004
Panel B: Cooking Pattern and Charcoal Use					
Number of years using charcoal stove	24,007	11,516	22,987	10,814	1,020
Head decides on aquisition of stove (dummy, 1= yes)	0,466	0,500	0,421	0,495	0,045
Distance to nearest charcoal market (in minutes)	4,945	4,060	4,236	4,752	0,710
Number of meals cooked last week	19,301	3,303	19,121	3,492	0,180
Number of meals cooked using charcoal	16,356	4,596	16,364	4,654	-0,007
Rice, main staple for the household (dummy, 1= yes)	0,497	0,501	0,488	0,501	0,008
Beans, main sauce (dummy, 1= yes)	0,476	0,500	0,522	0,500	-0,046
Amount of charcoal used last week (in Kg.)	19,193	8,781	19,734	11,735	-0,541
Total expenditure on charcoal last week (in TZS)	11072,760	4821,808	11498,890	7474,942	-426,130
Panel C: Demand for LPG stoves					
Household knows about LPG stoves (dummy, 1= yes)	0,983	0,130	0,983	0,129	0,000
Knows someone using LPG stove (dummy, 1= yes)	0,818	0,386	0,791	0,407	0,027
High start-up cost of LPG (dummy, 1= yes)	0,921	0,270	0,936	0,245	-0,015
Difference in taste of food (dummy, 1= yes)	0,031	0,173	0,020	0,141	0,011
Distance to the nearest gas dealer	17,836	14,423	18,022	14,081	-0,186
Observations	296		297		

Notes: $***p < 0.01, **p < 0.05, *p < 0.1$.

Table 4: Correlates of Attrition, Baseline - Endline: Probit Regression Results

	[1]	[2]	[3]
Treatment	0,106		
	-0,142		
Credit treatment		0,0929	0,101
		-0,176	-0,148
Subsidy treatment		0,119	0,129
		-0,175	-0,173
Age			-0,00398
			-0,00508
Household size			0,0303
			-0,0264
Years of schooling			-0,0396*
			-0,0221
Male dummy (1=yes)			0,135
			-0,159
Separate kitchen (dummy, 1= yes)			-0,0763
			-0,133
Residential house privately owned (dummy, 1= yes)			-0,248***
			-0,0963
Owns a bank account (dummy 1=yes)			-0,062
			-0,0883
Number of years using charcoal stove			-0,00832
			-0,00548
Head decides on acquisition of stove (dummy, 1= yes)			0,0323
			-0,18
Number of meals cooked last week			0,00437
			-0,0135
Intercept	-0,667***	-0,667***	-0,193
	-0,0973	-0,0973	-0,437
Observations	722	722	722

Notes: $***p < 0.01, **p < 0.05, *p < 0.1$.

Table 5: Charcoal Consumption at Baseline, Mid-line and Endline: Treatment and Control Group

	Baseline	Midline	Endline
Panel A: Amount of Charcoal in KG.			
Treatment	18,97	16,01	15,83
	(9,141)	(11,549)	(8,542)
Control	19,78	19,86	19,61
	(11,832)	(10,462)	(9,226)
Diff(Treated-control)	-0,82	-3,845***	-3.787***
Panel B: Value of Charcoal in TZS Treatment	11060,16	9328,25	9086,01
	(5081,011)	(6613,589)	(5008,947)
Control	11573,95	12241,70	11423,96
	(7667,924)	(7483,96)	(5072,572)
Diff (Treated-control)	-513,79	-2913,446***	-2337,947***
Obs	722	698	527

Notes: $***p < 0.01, **p < 0.05, *p < 0.1$.

Table 6: Impact of LPG Stoves on Charcoal Consumption

	[Midline]			[Endline]			[Mid. End. Diff.]
	[1]	[2]	[3]	[4]	[5]	[6]	[7]
Treatment	-0,318***			-0,274***			-0,044***
	-0,0771			-0,0829			-0,0046
Credit Treatment		-0,291***	-0,278***		-0,236**	-0,190**	-0,088***
		-0,0792	-0,0699		-0,0866	-0,0676	(0,0034)
Subsidy Treatment		-0,345***	-0,333***		-0,315**	-0,288***	-0,045***
		-0,108	-0,104		-0,11	-0,0977	(0,006)
Controls	No	No	Yes	No	No	Yes	
Observations	698	698	698	527	527	527	
R-squared	0.041	0.042	0.062	0.037	0.039	0.0.122	

Notes: $***p < 0.01, **p < 0.05, *p < 0.1$.

Table 7: LPG Stove Use: OLS Regression Results

	[Midline]		[Endline]	
	[1]	[2]	[3]	[4]
Credit treatment	0.900	0.221	-1.153	-0.618
	(1.032)	(1.125)	(1.355)	(1.045)
Age		0.0596		0.0596
		(0.0460)		(0.0469)
Household size		0.154		0.243*
		(0.235)		(0.116)
Years of schooling		0.260		0.359***
		(0.185)		(0.112)
Household monthly income (log)		0.332		-0.123
		(0.654)		(0.308)
Number of years using charcoal stove		-0.0506		-0.121*
		(0.0386)		(0.0631)
Gas run out (dummy)		-12.81***		-10.57***
		(0.980)		(0.660)
Incomplete knowledge on LPG stove use (dummy)		-11.72***		-5.190
		(0.756)		(5.389)
Distance to the nearest gas dealer		0.113		0.200
		(0.417)		(0.336)
Constant	11.38***	3.112	9.519***	8.060*
	(0.547)	(8.617)	(0.745)	(4.109)
Observations	296	296	241	241
R-squared	0.003	0.093	0.006	0.329

Notes: Standard errors clustered at the street level, $***p < 0.01, **p < 0.05, *p < 0.1$.

Table 8: Satisfaction With LPG Stoves: Probit Regression Results

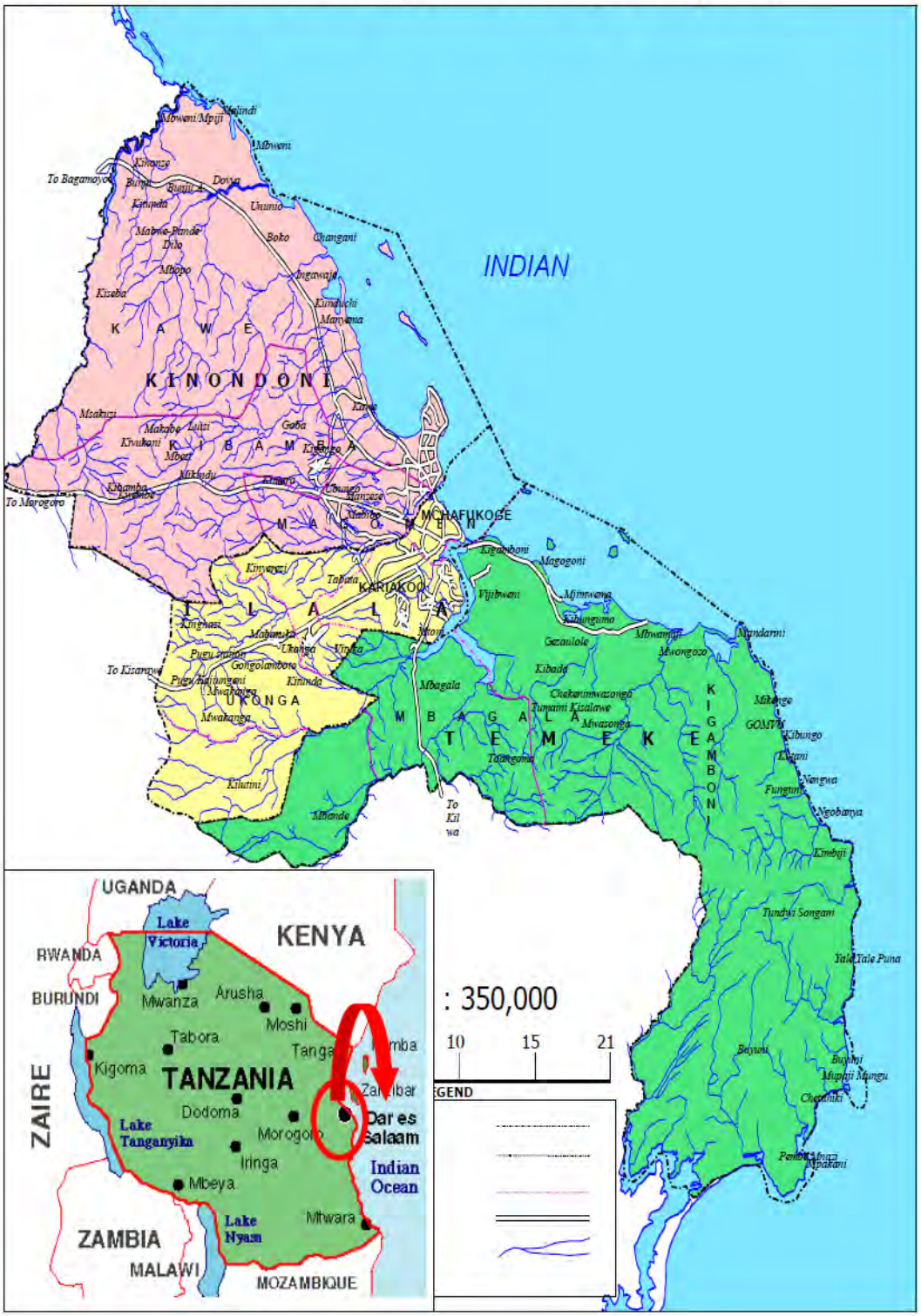
	Quality	Functioning	Food Taste	Cost	Convenience
Credit Treatment	-0.273	-0.309	-0.142	-0.237	-0.250
	(0.248)	(0.228)	(0.212)	(0.212)	(0.217)
Age	-0.00510	-0.000919	0.000793	0.00441	-0.00177
	(0.00755)	(0.00751)	(0.00967)	(0.00683)	(0.00808)
Household size	0.0795*	0.0448	0.0839*	0.0416	0.0878***
	(0.0408)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

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

Table A1 Reasons for not using LPG Stoves

	No.	%
Gas run out	5	0,07
Stove/parts mulfunction	3	0,04
Type of food cooked	2	0,03
Not confident on how to operate the stove	4	0,05
Non of the above	60	0,81
Observations	74	1,00

Figure 1: Map of Dar Es Salaam City Council Showing Municipalities

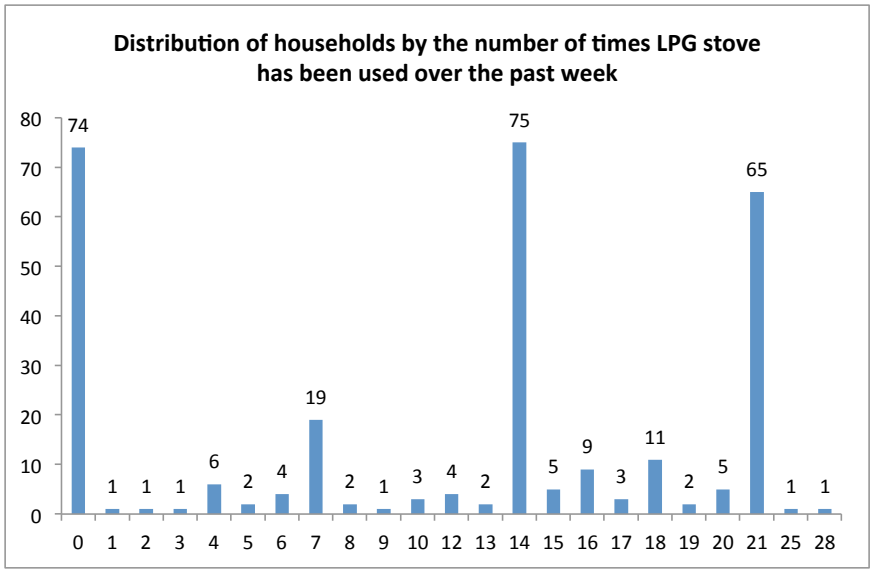


A1.pdf

Figure A2.
I). Subjects attending a training session.

II). Picture taken during home visits at follow-up survey.

Figure A3



A3.pdf

The International Growth Centre (IGC) aims to promote sustainable growth in developing countries by providing demand-led policy advice based on frontier research.

Find out more about
our work on our website
www.theigc.org

For media or communications
enquiries, please contact
mail@theigc.org

Subscribe to our newsletter
and topic updates
www.theigc.org/newsletter

Follow us on Twitter
@the_igc

Contact us
International Growth Centre,
London School of Economic
and Political Science,
Houghton Street,
London WC2A 2AE

IGC
International
Growth Centre

DIRECTED BY
LSE
UNIVERSITY OF OXFORD

FUNDED BY
UKaid
from the British people

Designed by soapbox.co.uk