Liquidity Constraint, LPG Stoves and Charcoal Consumption: Evidence from a Randomised Controlled Trial

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Research Questions and Motivations

Research Question:

- Does relaxing urban households' liquidity (financial) constraints induce them to adopt LPG gas stoves and reduce their charcoal consumption?

Motivations:

- Urban households in Sub-Saharan Africa (SSA) rely largely on charcoal to meet their cooking energy needs
  - In urban Tanzania (TZ), the proportion increased from 47% in 2001 to 71% 2007, a period which Tanzania experienced rapid economic growth
  - This is contrary to the predictions of the "Energy Ladder Theory"
- TZ consumes around 1 million tonnes of charcoal every year and half of it is consumed by a single city, Dar es Salaam

Research Questions and Motivations Cont.

Motivations cont.:

- Biomass fuel consumption has serious environmental, health, and climatic consequences
  - Cause for deforestation and forest degradation, especially in SSA (Campbell et al., 2007)
    - Results in loss of irreplaceable biodiversity, and disturbance of ecosystems
  - Indoor air pollution: 3.3% global burden of diseases, 2 million premature deaths (WHO, 2009).
  - Large effect on women and children who collects wood (Lewis and Pattanayak, 2012)
  - Contributes to climate change through enormous release of black carbon (Kandlikar, et al. 2009)

What we do

We:

- Collaborated with TZ's largest micro-finance institution and distributed LPG stoves in a Randomised Controlled Trial (RCT) set up
- Randomly allocated households into a "purchase through a subsidy" and "purchase on credit" treatments
    - The credit treatment included repayment everyday, repayment every week and repayment every month)
- Measure the impact of LPG adoption on charcoal consumption four months after the intervention

What we find

We document:

- High willingness to adopt LPG stoves: about 70% of the treatment households adopted the stoves

Average Treatment Effects on the Treated (ATT)

- Households who adopted the stoves reduced charcoal consumption by 47% four months after the stoves were distributed
- Those who acquired them through a subsidized price reduced charcoal consumption by 54%
- Those who acquired them on credit reduced charcoal consumption by 41%

Our Contributions

- The question "how to reduce biomass fuel use and improve efficiency" is an important one in developing countries
- Several previous studies attempted to identify the factors that promote adoption of ICS, and impact of ICS on fuel consumption, indoor air pollution, and health in a randomised set-up
  - Smith-Sivertsen, 2009: Guatemala
  - Hanna et al. 2015 Orissa, India
  - Miller and Mobarak, 2013: Bangladesh
  - Bensch et al., Burkina Faso
  - Beyene et al. 2014: Ethiopia
- Social networks, designs that meet households expectation (taste), affordability are important determinants of adoption
- ICS reduce fuelwood use, reduce indoor air pollution, improve health, and welfare of women and children

Our Contributions Cont.

- Few studies investigate adoption of modern (high-cost) cooking appliances and their impact
  - Edward and Langpap (2004): high start-up cost is the major factor that hiders transition to clean energy cooking appliances in urban Guatemala
  - Alem et al. (2014): economic status and education are important factors in urban Ethiopia
- Both these studies use **observational data**
  - Difficult to infer a causal relationship between income and adoption of modern cooking appliances because of endogeneity

Our Contributions Cont.

- We identify the impact of relaxing financial constraints on adoption of high-cost and high-quality LPG stoves and their impact on charcoal consumption using a randomised controlled set-up
- Africa's tropical forest resources have significant carbon sequestration capacity but are at greater risk than those in other countries
- During 2000-2010, 30 million ha of forest (a size equivalent to Finland) was cleared in Africa, 80% of it was for charcoal and fuel wood
- We shed light on the possible environmental benefits of targeting the price of LPGs to save the remaining forest resources of Africa!

Experimental Design

Study Area

- Dar es Salaam, the largest city in Tanzania where more than 70% use charcoal, 25% use firewood, less than 3% use LPG and electricitiy
- Two districts Kinondoni and Temeke (separated by another district called Ilala)
- Tanzania recently discovered huge natural gas reserve (30 trillion cubic feet): Large explorations are underway
  - Expected to play significant role in the economy and household energy transition
- However, this transition could be constrained by the high start-up cost of LPG stoves
- Our study therefore comes at an important point

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

Experimental Design

Sample Selection and Design

- The selected distrits of Kinondoni and Tekeme have 34 and 30 wards respectively
- We selected four wards (two from each district), which are the residence of the majority of low-income households in Dar
- We chose 4 sub-wards (also called streets) from each ward = 16 wards in total
- We allocated 722 households into these sub-wards at the baseline
- Eligibility criteria included not owning LPG and Kerosene stoves but used charcoal as the main fuel
- We assigned our treatments at the street-level (to reduce the effect of spill-overs)

Experimental Design

Timeline and Implementation

- October-November 2014, we conducted a fact finding (qualitative and quantitative) survey to get background information
  - We acquired useful information on WTP for LPG stoves, awareness, reasons for not owning LPG stoves etc.
- March-April 2015: a comprehensive baseline survey
- May 2015, a small pre-intervention survey and distribution of LPG stoves
- Out of 425 treatment households, only 296 (70% decided to take up the Stove either on credit/subsidy)

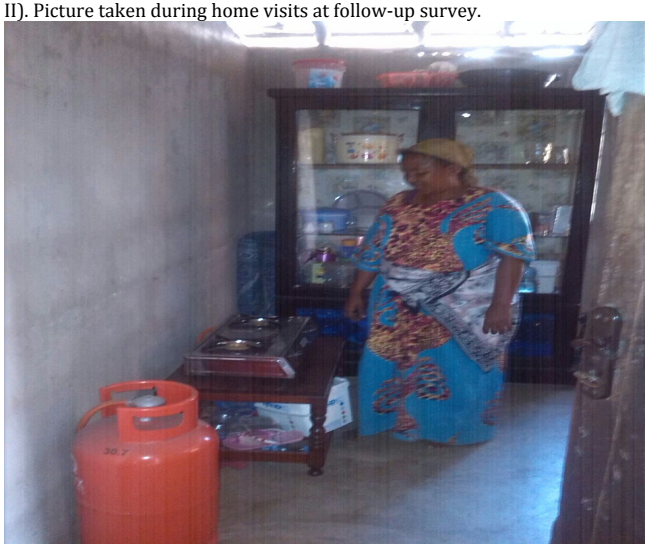
Experimental Design

Timeline and Implementation

- We implemented our intervention in collaboration with one of Tanzania's biggest micro-finance institutions: Women Advancement Trust, WAT-SACCO
- WAT-SACCO is known and reputable in helping the poor
- Helped us to distribute the LPG stoves to "credit" households
- We took the necessary care to reduce the likelihood of default in payment (asked guarantee letter from ward leaders)
- The intervention was implemented in late May, 2015
- Follow-up survey was conducted in late September, 2015
  - We chose end of Sept. because TZ scheduled the national election end of October

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

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



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Baseline Characteristics
Descriptive Statistics

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

Baseline Characteristics
Descriptive Statistics

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
High cost of refilling is main reason for not owning LPG (dummy, 1= yes)	0,701	0,458
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	

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Charcoal Use: Baseline and Follow-up

Mean Differences

Table 4: Charcoal Consumption at Baseline and Follow-up, Treatment and Control Group

	[Baseline]		[Follow-up]		[Diff.]		
	Mean	SD	Mean	SD	Mean	SD	Obs.
Panel A: Amount of Charcoal in KG.							
Treated	19,24	9,18	13,52	17,33	-5,72	1,14	296
Control	19,40	11,70	19,71	10,02	-0,31	0,87	314
Diff	-0,16	0,85	-6,19 ***	1,14			
Panel B: Value of Charcoal in TZS							
Treated	11112,86	5163,02	8354,46	6541,76	2758,41	483,57	296
Control	11279,09	7455,48	12125,99	7191,85	-846,90	584,59	314
Diff	-166	522	-3772***	558			

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

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Results
ATT on Charcoal Consumption

Table 5: Impact of LPG Stoves on Charcoal Consumption

	[1]	[2]	[3]
	[Charcoal/Week - kg (log)]	[Charcoal/Week - kg (log)]	[Charcoal/Week - kg (log)]
Treatment	-0.475***		
	(0.0881)		
Credit Treatment		-0.414***	-0.384***
		(0.0938)	(0.0783)
Subsidy Treatment		-0.541***	-0.527***
		(0.134)	(0.126)
Intercept	2.899***	2.899***	2.784***
	(0.0369)	(0.0369)	(0.248)
Controls	No	No	Yes
Observations	593	593	593
R-squared	0.091	0.094	0.122

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

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Results cont.
Satisfaction with LPG stoves

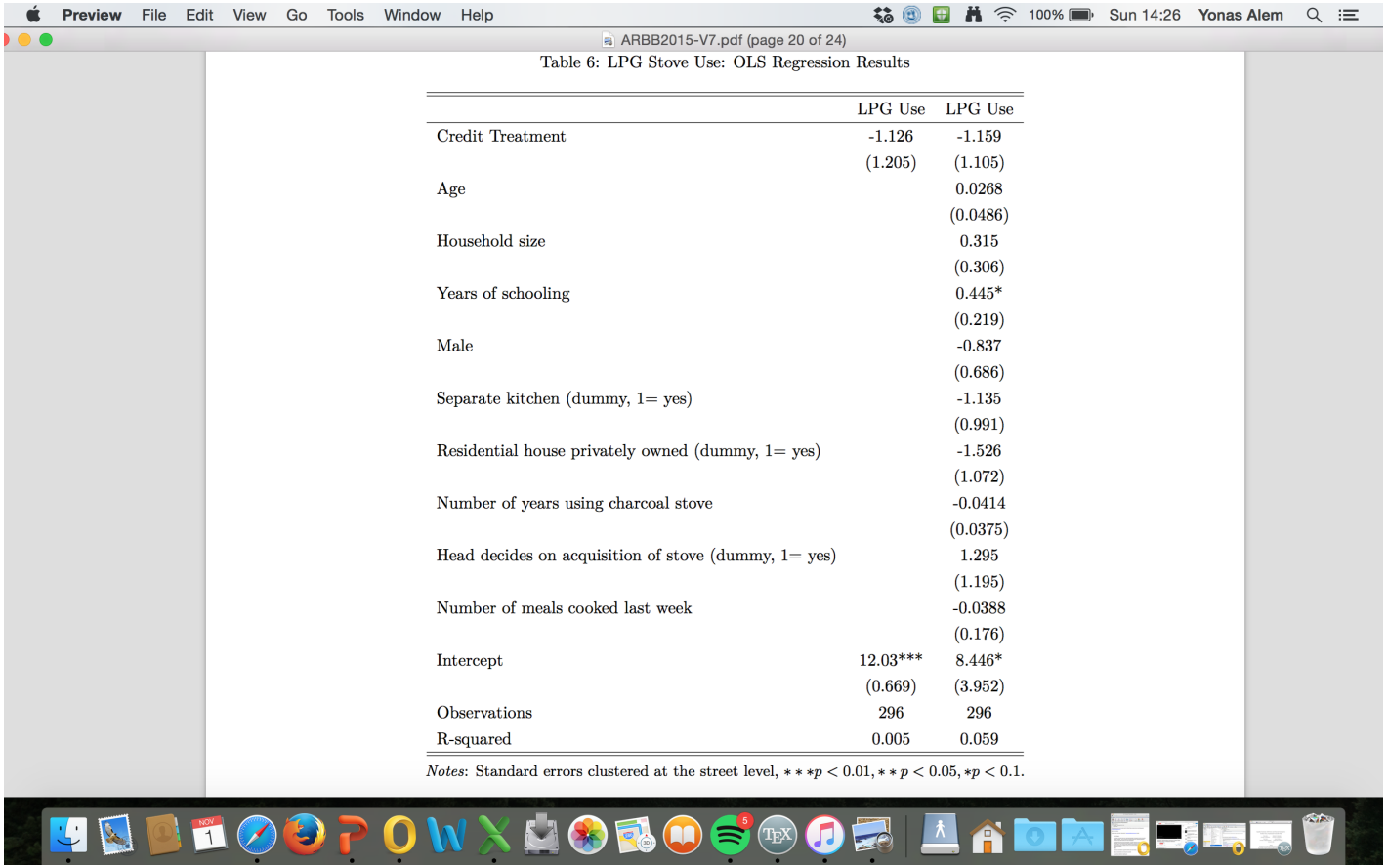

Table 6: LPG Stove Use: OLS Regression Results

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

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

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Results Cont.

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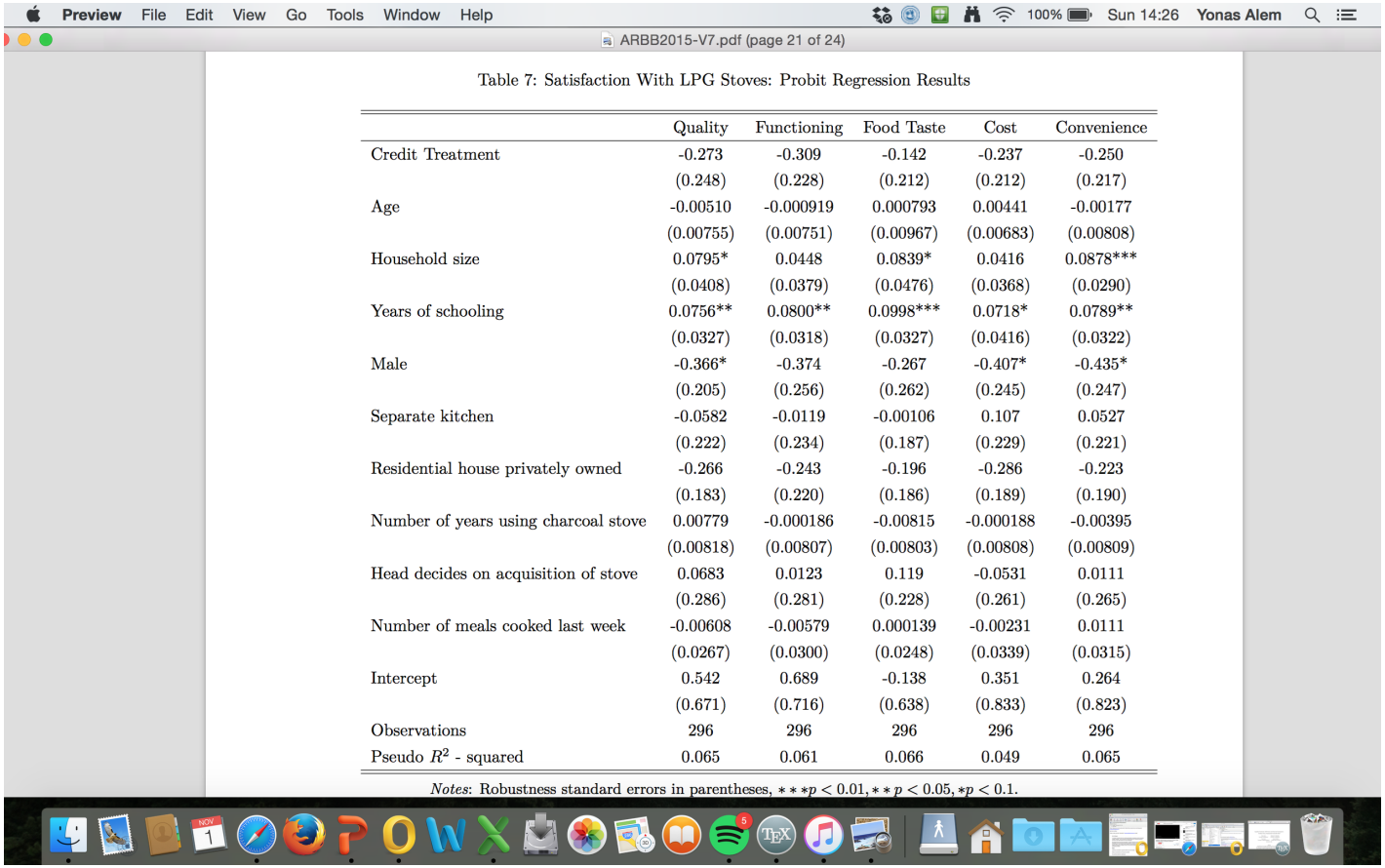

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Table 7: Satisfaction With LPG Stoves: Probit Regression Results

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

Conclusions

- Charcoal, produced to meet urban households' cooking needs has been the most important cause for deforestation and forest degradation in Africa
- One factor that hinders households' transition to clean energy sources is the high start-up cost of modern cooking appliances
- We collaborated with TZ's largest micro-finance and ran an RCT of LPG distribution on credit and subsidy
- We document a large reduction (47.5%) in charcoal use by adopting households
- Those who adopted through a subsidy used the stove more often and reduced larger amount of charcoal (54%) than those who adopted on credit (41%)
    - Possible reason: we conducted the follow-up two months before the repayments have been completed for credit households - they probably did not feel owning the stove

Conclusions

- Millions of ha forest lands of Africa are cleared every year (80%) to meet cooking fuel needs
- Rough computation shows that only our sample of 722 households consume 0.6 ha of forest each week at the baseline (before the intervention)
- Our LPG stove intervention shortly reduced this by half for the treatment group!
- Given Africa's tropical forests documented carbon storage capacity, reducing charcoal consumption and deforestation would provide benefit to the society at large
- Simple policy interventions (e.g., reduceing import duties on LPG stoves) could induce adoption and hence charcoal reduction
- This is the most important message of our study which should be picked up by policymakers, donors and other stakeholders

Conclusions cont.

- **Thank you for your attention!**