Electric cooking and sustainable development: experimental evidence from eastern D.R. Congo

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Abstract

In this experiment (targeted sample size = 1500 households), we ask whether electric cooking can be a credible alternative to charcoal cooking in the context of a low-income country, study the impact on charcoal demand, consumption patterns and the formation of pro-social motivations. Specifically, we randomly distribute electric pressure cookers to households connected to a reliable and green electricity grid in Goma in Eastern Democratic Republic of Congo where over 90% of the population relies on charcoal as their primary energy fuel. The majority of this charcoal is illegally produced in protected forests and is a key income source for several armed groups . We design different treatment arms to improve adoption of cookers, leveraging both selfish and pro-social preferences of households.

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Contents

1 Context

Worldwide, around 2.6 billion people remain dependent on biomass fuels for cooking (ESMAP, 2021), posing serious environmental costs. Among them, close to 2 billion people now have access to electricity (ESMAP, 2021). This opens opportunities, the more so since technological innovations in Electric Pressure Cookers (EPC) have made cooking with electricity a cheaper and faster alternative (ESMAP, 2020; Leary et al., 2021). Opportunities are especially promising in Eastern Africa, where electricity grids are becoming more reliable and reaching more people, and because EPCs are well-suited for the East African kitchen (Batchelor et al., 2022; Leary et al., 2021). Yet, from the literature, we know that even cost-effective new products often face low adoption rates (BenYishay & Mobarak, 2019; Cohen & Dupas, 2010; Kremer & Miguel, 2007). We offer experimental evidence assessing the optimal delivery mechanism to maximize the adoption and use of EPCs.

Due to the novelty of the product, the associated information gap and the high upfront cost (around 70usd per EPC), selling the EPC at market price may lead to a low take up.[1] We will test a distribution model with a 100% subsidy provided by a local electricity distributor, Virunga Energies (VE). As the energy distributor would increase its electricity sells, such a high subsidy is cost-effective from its perspective if EPC use is sufficiently high.[2] Furthermore, we provide a free electricity voucher to a subgroup of beneficiaries to overcome the learning cost of EPC and make the transition easier at the beginning from the perspective of the household. Finally, we cross-randomize this treatment with a focus on social benefits of EPC adoption to address a recently identified research gap (Jayachandran, 2022), i.e., how information on social benefits affects people's demand for environmentally friendly technologies, and how environmental preferences emerge among citizens of low-income countries.

Our experiment takes place in Goma, the provincial capital of North-Kivu in Eastern Democratic Republic of Congo (DRC). Goma's 1.5 million inhabitants rely on charcoal as their primary source of cooking. In a survey conducted in 2019, 95% of households in Goma used charcoal every day. This was confirmed by a pilot of our experiment conducted in September 2021. In addition to the health issues caused by indoor air pollution, charcoal is expensive and constitutes a financial burden for poor households. On average, households in Goma spend 30 US$ per month on charcoal, which is a third of household expenses (Mvukiyehe et al., 2016).

A majority of the charcoal is illegally harvested and produced in the nearby forests of Virunga National Park (VNP) – a UNESCO world heritage site in danger, and controlled by several armed groups. The footprint of charcoal production in VNP has increased by 18% between 2020 and 2021, threatening the habitat of endangered Mountain Gorillas, and carbon dense forests (source: VNP based on satellite images). At scale, the social benefits of EPCs may include biodiversity conservation and and peace promotion by reducing financing to armed actors.

2 Experimental design

We build on the lessons learnt from a pilot organized in September and October 2021 with 55 EPC from a different manufacturer. This pilot confirmed the reliability of EPC, the energy and cost saving compared to charcoal. They were received positively by the pilot users and 42 of them reported that

[1] See Berkouwer and Dean, 2022 on the low adoption of improved charcoal cookers in Kenya. In their experiment, the upfront cost, information gap and learning curve are less important than in our experiment.

[2] We hypothetize that the energy provider can reimburse the initial subsidy in about one year through increased electricity consumption. Still, one might oppose free distribution, arguing that 'reference dependence' may limit future willingness to pay for EPCs. A seminal paper by Dupas (2014) – looking at the long-run adoption of subsidized bed nets – showed however that people did not get used to handouts; they got used to bed nets. Bensch and Peters (2020) show that this also holds for improved biomass cooking stoves, concluding that "if rapid adoption is a policy goal, subsidization of free distribution does not hamper the establishment of future market-based distribution".

they were still using them 10 months after.

In the experiment at scale discussed here, we plan to enroll around 1,500 households. They will be randomly selected from Virunga Energies' client base. Eligibility criteria to be part of the study are:

- Household client of Virunga Energies in Goma
- Having an individual electricity meter
- Consuming between 3 and 30usd of electricity on average per month in the six months before the baseline (approximately excluding the bottom and top 5% electricity consumers)
- Being the primary user of the electricity connection
- Using charcoal or charcoal residuals as the primary source of cooking fuel
- Not being enrolled in another on-going study to prevent survey fatigue

The core intervention (denoted T below) consists of 1,000 randomly selected clients receiving a free EPC. The EPCs are worth around 70usd in Kenya and Tanzania and are not available in Eastern DRC at the start of the experiment. They will be distributed to beneficiaries during demonstration sessions organized by Virunga staff and extension workers ("ambassadors"). The demonstration sessions will include about 15 to 20 participants per session, and last around 2 hours. Staff, ambassadors, and participants will cook local recipes together. EPCs will be connected to electricity meters to show clients the actual energy usage of the cookers. Participants will share the meals they cooked together, allowing them to taste the food cooked with the EPC. Each participant is assigned to a specific ambassador who will assist and monitor them in the first two months. A second group of 500 randomly selected clients will not receive a cooker, and serve as the control group (C).

We will further randomize EPC beneficiaries in four treatment arms to explore mechanisms of adoption:

2.1 Electricity voucher treatments arms

2.1.1 EPC with electricity voucher ("V1")

For budget-constrained households, with a set budget for energy purchases, devoting part of their current budget to pre-paid electricity to experiment with a new device instead of charcoal represents a risk. Households in V1 receive a 5usd (20kwh) voucher of free electricity for their meter. This treatment arm intends to allow beneficiaries to try the cooker for about 25 meals without enduring any monetary cost, hence allowing them to continue buying charcoal in case they are not satisfied with the EPC.

2.1.2 No voucher ("V0")

Participants in V0 receive the EPC during a demonstration session (our core intervention), but do not receive a 5usd voucher of free electricity

2.2 Pro-social motivation treatment arms

To understand the effect of pro-social preferences on primary outcomes, we cross-randomize V1 and V0 with a nudge.

2.2.1 Pro-social preferences – Nudge ("N1")

During the demonstration sessions, a module of around 30 minutes will detail to participants the consequences of charcoal production on the conservation of VNP (deforestation and destruction of habitats for flagship species, including Mountain Gorillas and Chimpanzees) and the impact of illegal charcoal production on the revenues of armed militias. This module will be designed with Virunga's Environmental Education department and conducted with experienced rangers.

To reinforce the impact of the nudge, a small sticker designed by a local artist will be put on the EPC. The sticker will convey a simple message around the benefits of using eCooking instead of illegal charcoal to protect the environment and promote peace.

2.2.2 Pro-social preferences -Control ("N0"):

Participants in N0 receive the EPC during a demonstration session (our core intervention), but not the nudge.

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To avoid contamination between treatment arms, all participants in a given demonstration session will be assigned to the same treatment arm ({V0, N0}, {V0, N1}, {V1, N0}, {V1, N1}), and randomization will be done based on spatial clusters (see 3.1.2). In addition, ambassadors will also be assigned to a single treatment arm.

2.3 Sample size

The approximately 1,500 participants will be split in the five treatments as below (Table 1):

Table 1: Sample size for each treatment arm

	Electric Pressure Cooker (T)		Control(C)
	Electricity voucher (V1)	No electricity voucher (V0)	
Pro-environment nudge (N1)	N=250	N=250	N=500
No nudge (N0)	N=250	N=250	

3 Implementation

3.1 Timeline and protocol

The experiment will be implemented in two waves of similar sample size. The city of Goma is divided in electricity distribution zones. At the beginning of the experiment, VE is the main energy distributor for 26 of these zones. In wave 1, we randomly sample eligible participants in zones 14 to 26. Wave 2 focuses on zones 1 to 13. This is done to avoid conflicts with another study conducted in zones 1 to 13 at the same time of our wave 1. Participation in the study consists of one initial phone call, one pre-intervention survey, the participation in a demonstration session, three home visits by ambassadors, and two post-intervention surveys.

3.1.1 Recruitment of participants and baseline survey

Participants are recruited using a three-step procedure. First, we use VE' database to filter non-eligible households based on *i-* their connection type (keeping households, excluding businesses), *ii* - type of electricity meter (keeping individual meters, excluding shared meters), and *iii-* distribution zone. We joined this dataset with past electricity purchase to only keep clients purchasing on average 3 – 30usd of electricity per month in the six months before the baseline. We then draw a random sample of eligible clients.

Second, a short text message is sent by VE to the sample of clients to inform them that they will be contacted by an independent research team which helps VE to conduct a survey about cooking habits in Goma. Enumerators then call clients to confirm that they are a household, that they are the main user of the electricity meter, and that they primarily use charcoal or charcoal derivatives as their main cooking fuel (targeted length of a call = 5 - 10min). If the answers are yes to these three questions, enumerators invite respondents to participate in an in-person survey.

Third, an in-person baseline survey is organized with the main adult household member in charge of cooking (excluding domestic workers). The survey starts by confirming that the respondent is the main person in charge of cooking. It covers several topics including food habits, cooking habits, energy consumption, asset wealth, health, household demographics, and pro-social attitudes. The survey stops if the main energy source is not charcoal. The survey does not mention EPC or the experiment. We designed the survey to last under 40 minutes.

3.1.2 Randomization

After the baseline, eligible participants are randomly assigned to one of the five experimental arms. Using the GPS coordinates of participants collected at baseline, we create spatial clusters of clients using Euclidean distances. To avoid contamination between arms, each client living within a given threshold is assigned to the same cluster (cluster randomization). A targeted distance of 150meters will be used based on initial tests with mock samples. This distance may be slightly lowered or increased to attain correct balance between treatment arms or having enough participants in each arm. Each cluster will be assigned to one treatment arm. To maximize power, we stratify randomization by charcoal and electricity spending at baseline.

3.1.3 Demonstration sessions and ambassadors' visits

Participants assigned to T ({V0, N0}, {V0, N1}, {V1, N0}, {V1, N1}) are informed by phone that they won a free EPC and are invited to participate in a demonstration session where they will receive their EPC. The session will be scheduled 7 to 15 days after the phone call. Participants are invited to a specific session but will be given the opportunity of being reallocated to another session of the exact same treatment group in case they are not available during the proposed time slot. An information session on the environmental and security consequences of illegal charcoal consumption will be provided to participants assigned to N1. Participants assigned to V1 will receive their electricity voucher. All participants will be assigned to an EPC "ambassador". At the end of the demonstration session, participants will return home with the EPC.

Ambassadors are selected among regular users of EPC. For wave 1, we reached out to the 50 beneficiaries of the September 2021 pilot. Those who still use the EPC in July 2022 (n=42) are informed about the opening of ambassador positions and about the procedure to apply. For wave 2, participants from the pilot or new beneficiaries from wave 1 might be chosen. In total, we will target having around 25 ambassadors per wave.

Between the distribution of the EPC and the endline survey, ambassadors will assist in the demonstration sessions and visit each beneficiary three times, to collect monitoring data on the usage and assist beneficiaries in using the EPC if needed. We anticipate visits to last around 30 minutes.

3.2 Primary outcomes

The key hypothesis is that receiving an EPC along with proper instructions in the demonstration session will increase electric cooking uptake among treated households (measured by electric consumption) and decrease charcoal consumption. EPC users are expected to decrease their spending for energy and we will track the effect of the programme on non-energy related spending. Finally, we will measure the impact of the programme on the formation of pro-social motivations.

The first post-intervention survey will be organized around 6 six months after the distribution of EPCs. A second post-intervention survey will be organized another six months later (12 months after the distribution of EPCs).

Table 2: Primary outcomes

Outcome	Measurement
Usage of the cooker	Monthly electricity consumption proxied by monthly electricity purchases (in usd) from m-6 to m+12: the outcome will be computed using the universe of electricity transactions from all VE clients. Transactions will be summed for every month to obtain monthly consumption.
Charcoal consumption	Average daily weight of ashes: During the first post-intervention survey, a 10L bucket will be distributed to participants. We will ask participants to dispose all their ashes in the bucket. About seven days later, the enumerator will come back to weigh the ashes. The total weight will be divided by the number of days during which the households disposed her ashes in the bucket.
	Monthly spending on charcoal (in usd): A recall question will be asked during the survey. This will be asked twice (when the bucket is given to the household and when ashes are weighted). We will average these two answers to filter out noise.
	Dummy variable equals 1 if the respondent uses charcoal coming from VNP
Consumption	Spending (in usd) on non-energy related items (recall question, simplified consumption module)
Pro-environmental motivations	Contribution to a dictator game during which participants will be given the opportunity to contribute up to 5usd to local NGOs.

Secondary outcomes will also be analyzed. They will include cooking time, reported health condition, perception towards environment and violence, locus of control.

3.3 Power calculation

Based on data from the pilot with 50 cookers, we will be sufficiently powered at 0.8 to measure an estimated treatment effect size below 4kwh of monthly electricity consumption (+0.28sd) with 250 beneficiaries per treatment arm. For charcoal consumption, our study should be powered to detect a 2kgs change in monthly charcoal consumption (5% change) with about 250 participants per treatment arm. This value is well below what our partner, VNP, would consider as efficient to lower illegal charcoal trafficking (25%).

4 Analysis

We run all regressions below at the household level.

4.1 Balance check

We will test for whether baseline variables are balanced across treatment groups. We will estimate the following regression, where y_i denotes the baseline covariates for household i:

$$y_i = \beta_0 + \beta_1 \cdot T_1 + \beta_2 \cdot N_1 + \beta_3 \cdot Wave + c \cdot Strata + \epsilon_i$$

For each variable, we will run an F-test of the joint hypothesis: H0: $\beta_1 = \beta_2 = 0$. Given the long list of baseline variables, we will not be surprised if some variables reject this null hypothesis.

4.2 Attrition

To limit potential attrition and help track respondents at a later point in time, we will take their pictures and collect phone numbers of two relatives. When analyzing the data, we will create a binary variable indicating if a household's questionnaire is missing, then regress this variable on treatment assignment and household characteristics, to check whether our data suffers from differential attrition.

4.3 Effect of EPC ownership on our primary outcomes

We rely on the random distribution of the EPC and additional treatments (electricity vouchers, pro-social nudge) to measure the Intention to Treat (ITT) effect of the program. Unless stated otherwise, we will control in each regression for baseline electricity consumption, baseline charcoal spending (stratification variables) and implementation wave (dummy variable). We will implement a doubly-robust lasso procedure to select additional covariates (Belloni et al., 2014) and cluster errors by randomization cluster.

4.3.1 Electricity consumption (usage of the cooker)

We estimate an event study model to use the panel dimension of the electricity consumption data ($y_{i,t}$):

$$y_{i,t} = \beta_0 + \sum_{t=-6}^{12} \beta_t \cdot T_i + \epsilon_{i,t}$$

Where T_i is a dummy variable for receiving the cooker and t is the month since receving the cooker. Our preferred specification will use electricity consumption data (kwh purchased) in level.

4.3.2 Charcoal consumption, non-energy related consumption, pro-social motivations

For all other primary outcomes, all specifications take the following form:

$$y_i = \beta_0 + \beta_1 \cdot T_i + \gamma X_i + \epsilon_i$$

where y_i is the outcome of interst, T_i a dummy variable for receiving the EPC and X_i a set of control variables selected through the lasso procedure and stratification variables. As in Berkouwer and

Dean (2022), our preferred model uses log charcoal weight and spending because switching to EPC is expected to reduce charcoal usage by a fixed percentage relative to baseline usage. If 0 are frequent in charcoal weight or spending, we will implement this transformation using inverse hyperbolic sine (IHS). We will also run the regressions using charcoal ashes in kilograms and spending in usd. When estimating the impact of EPC on the contribution to a dictator game, we will use the level of the contribution.

4.4 Mechanisms and heterogeneity

Our experimental design allows us to test the following predictions for mechanisms:

Prediction 1: Relaxing the budget constraint by providing a 5usd voucher increases cooker usage (1.1), and decreases charcoal consumption (1.2):

$y_i = \beta_0 + \beta_1 \cdot T_i + \beta_2 \cdot V_i + \beta_3 \cdot T_i \cdot V_i + \gamma X_i + \epsilon_i$

Null hypothesis: $\beta_3 = 0$

Prediction 2: Leveraging pro-social motivations increases cooker usage (2.1), decreases charcoal consumption (2.2) and increases contribution to the lab in the field game (2.3)

$y_i = \beta_0 + \beta_1 \cdot T_i + \beta_2 \cdot N_i + \beta_3 \cdot T_i \cdot N_i + \gamma X_i + \epsilon_i$

Null hypothesis: $\beta_3 = 0$

As a robustness check, we will estimate a fully interacted model. We will use two-sided tests to be conservative. We will conduct further heterogeneity analyses of the different specifications with respect to:

- Baseline electricity consumption
- Baseline wealth
- Baseline attitudes towards the environment
- Baseline attitudes towards charcoal and conflicts

4.5 Multiple hypothesis testing

Following Benjamini et al. (2006), we will use false discovery rate corrections to account for multiple hypothesis testing across our primary outcome variables. Therefore, for each hypothesis test, we will report two values:

- The usual p-value from a Wald test
- False discovery Rate q-values, taken across primary outcomes

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