REDGAS: RANDOMISED EVALUATION OF THE DEMAND FOR LIQUEFIED PETROLEUM GAS STOVES AND THE EFFECTS ON AIR POLLUTION AND HOUSEHOLD HEALTH IN BURKINA FASO

Pre-analysis plan

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Abstract

Background: The REDGAS study evaluates an intervention to reduce air pollution in Burkina Faso by encouraging households to switch from wood or charcoal to gas as the main cooking fuel.

Method: The REDGAS study is a randomized evaluation involving 4400 individuals from 820 households randomly selected from the population. 58% of sampled households will be randomly selected to receive an offer to purchase a gas stove. A "credit" treatment or a "subsidy" treatment will be associated with each offer. Individual exposure to fine particles will be measured following the interventions. The effects of each treatment on gas uptake and intensity of use, and the effect of these two variables on individual exposure to air pollution will be evaluated.

Discussion: The REDGAS study proposes to analyze the effects of access to credit, on the one hand, and of subsidized price, on the other, on the adoption of a cooking fuel emitting low levels of fine particulate matters, as well as on a set of variables associated with its use (exposure to $PM_{2.5}$, respiratory symptoms, time use or greenhouse gas emissions for instance). It exploits the latest developments in stove use monitoring and air quality measurement techniques to generate accurate data on the intensity of use of gas stoves and its impact on household air pollution.

Keywords: household energy, cooking, air pollution, credit, subsidy.

1. Overview of the study

1.1. Motivation

In 2019, one third of the world's population, approximately 2.6 billion people, used solid fuels to cook their food (WHO 2021). Recent waves of the Global Burden of Disease survey (GBD) have shown that household air pollution from burning wood, charcoal or cow dung for instance is a major public health issue. This pollution is responsible for approximately 4 million deaths each year worldwide (WHO 2018). For this reason, the transition to less polluting cooking solutions is on the agenda of development and health organizations. To date, much of the international effort in this area has focused on promoting improved stoves which, although more efficient, still use solid fuels. The resulting health impacts have been disappointing (Hanna et al. 2016, Mortimer et al. 2016).

In contrast, strategies aimed at encouraging households to switch to more modern and less polluting cooking fuels – or sources of energy - have received limited attention from development aid agencies and researchers alike. Yet, low-emission technologies such as ethanol cookers, electric pressure cookers, or LPG stoves allow for a significantly less polluting cooking experience than advanced improved biomass stoves. Laboratory tests have shown that they can reduce particulate matter emissions by a factor of at least 6 compared to even the cleanest burning biomass stoves, which places them in the highest performance tier of the 2018 ISO protocol for cookstove emissions (Champion et al. 2021, Jetter et al. 2015, Shen et al. 2017). Recent experimental evidence from field trials suggests that the pollution reductions achieved by LPG in real life conditions also dominate those of existing improved stoves (Pope et al. 2021).

Ethanol stoves, LPG stoves and more recent innovations such as electric pressure cookers are relatively expensive devices and their prices far exceed that of traditional wood and charcoal stoves. This might explain that penetration rates remain low, even for a mature technology such as LPG stoves, and even in countries where the cost of the fuel is heavily subsidized as is currently the case in Burkina Faso. Subsidies are a conventional policy response adopted by governments when demand for cost-effective products with high social benefits is low. Subsidized LPG stoves have been distributed on a broad scale in India, Indonesia or Peru in recent years, with positive results in terms of fuel switch in Indonesia and more mixed results in India and Peru (Calzada and Sanz 2018, Imelda 2020, Kar et al. 2019). An alternative strategy is to help credit-constrained households finance the capital cost of switching to clean fuels by providing consumption loans or flexible payment facilities. This approach has been piloted on a smaller scale by NGOs in several sub-saharan African countries (Hsu et al. 2022, Gold Standard 2014). Which of these two approaches most cost-effectively contributes to reducing average levels of exposure to household air pollution is an empirical question which hasn't been addressed in the literature. On the one hand, subsidies might achieve higher take-up rates because they address both willingness-to-pay and liquidity constraints problems while loans are mainly an answer to the second problem. Subsidies also facilitate learning processes, both directly through product experience and indirectly through social networks (Dupas 2014b, Fischer et al. 2019, Meriggi et al. 2021). On the other hand, subsidies come with concerns regarding psychological sunk cost effects, over-selection effects, and potential anchoring (or entitlement) effects which might result in low usage rates or low future demand for the promoted technology (Dupas 2014a, Meriggi et al. 2021).

The main motivation for the REDGAS study is to produce results which will inform public policy debates on the most cost-effective strategies to support the adoption of low-emission cooking technologies in developing countries. To this end, the study will evaluate the effects of introducing capital costs subsidies and consumption loans on the adoption and intensity of use of LPG stoves in Burkina Faso. It will also generate evidence on the magnitude of sunk costs, learning, selection and entitlement effects. Finally, it will provide estimates of the effects of the interventions on household air pollution.

1.2 Sample

The study sample was drawn in November 2019 in the Centre Sud region of Burkina Faso based on a spatial sampling strategy. A list of urban enumeration areas for the target communes (Kombissiri, Manga and Pô) was obtained from the *Institut National de la Statistique et de la Démographie* (INSD). The most densely populated areas in the urban centre of the three target communes were selected and cut into blocks of equivalent size using QGIS software. 4215 GPS points at least 60 meters apart were drawn within the blocks. Supervisors from the data collection team visited each GPS point and used a random walk established by an algorithm built into the data collection software to identify a household to be surveyed from the GPS point. All households sampled as a result of the random walk were asked to complete an eligibility questionnaire. In cases where households were not eligible, supervisors were instructed to return to the original GPS point and conduct another random walk in a different direction. The eligibility criteria were : (i) Not belonging to a household that has a gas stove or electric range, (ii) Belonging to a household that cooks at home, (iii) Not belonging to a household that produces dolo beer[1].

Households who consented to all aspects of the study were invited to complete the various baseline survey questionnaires, including participation in a five-day cooking practice survey and air pollution measurements. 831 households were included in the sample, and fuel consumption and air pollution measurements were obtained for 820 of them.

Since the sampling of the households in 2019, 3 surveys were conducted. An experiment unrelated to the REDGAS study was also implemented during the peak-period of the COVID-19 crisis (Badolo et al. 2021):

- Baseline in December 2019-March 2020

- First follow-up survey in June-July 2021

- Interventions related to COVID19 from July to December 2021.

- Second follow-up survey in December 2021

The COVID19-related experiment divided the sample into four groups and has crossed on the one hand an informational treatment aiming at complementing public information campaigns

[1] The production of dolo beer is energy intensive and dolo brewers have a consumption of wood which far exceeds the consumption of the average household.

on the 2019 coronavirus disease and on the other hand an economic treatment consisting of non-conditional cash transfers which aimed to stimulate the adoption of protective measures by households (hand washing, wearing of masks, etc).

Group 1: In this group, every month during 3 months, households received an unconditional cash transfer sized to cover the amount of their monthly soap and mask expenditure.

Group 2: Households in this group received information about COVID19. The information messages were disseminated in the form of video animations at the end of the first follow-up survey, and through one weekly message transmitted by recorded calls during a period of three months The messages were designed to inform about the existence of COVID19, the associated risks, and preventive actions to protect themselves and the others. They received a cash transfer equivalent to the total amount given to group 1 households, in a single payment after the second follow-up survey.

Group 3: Every month during 3 months, households assigned to this group received an unconditional cash transfer sized to cover the amount of their monthly soap and mask expenditure, and were also exposed to the 'information' treatment (according to the same terms as households in group 2).

Group 4: Households assigned to his group served as a control: they received the delayed cash transfer and did not receive any information.

1.3 Description of the interventions

Technology

LPG is a relevant technology for addressing the problems associated with the use of solid fuels for several reasons. Firstly, LPG is very clean burning and emits low amounts of fine particulate matter and carbon monoxide, the main 'killers in the kitchen'. A recent study commissioned by the US Environmental Protection Agency concluded that LPG meets WHO recommended emission levels in 90% of 89 laboratory tests conducted on five commercially available gas stove models (Shen et al. 2018). LPG is also very fast and convenient to use which suggests that it can provide additional time-saving benefits that cannot be achieved with improved biomass stoves. From a series of 47 boiling tests conducted in Nepal in 2013, Ojo et al. (2015) conclude that LPG stoves significantly reduce the time required to boil 10 liters of water by about 50% and provide a time saving of about 45 minutes compared to a sample of improved biomass stoves. Moreover, LPG has a low greenhouse gas emission factor although a very small share of global LPG production is of renewable origin[2]. Finally, a national filling center and a large LPG distribution network already exist in the country where the study takes place, Burkina

[2] When carbon dioxide, methane and nitrous oxide are taken into account, the emission factor from stationary combustion of LPG is less than half that of firewood according to the Emission factor database of the Intergovernmental Panel on Climate Change (IPCC 2006).

Faso, which make a scale-up in the use of LPG by households feasible over a relatively short time horizon.

We chose to conduct the evaluation with a single-burner stove model that is widely used in West Africa. This stove model is known as the "Telia stove" in Burkina Faso. It can be described as a very large camping stove size product consisting of a 6 kg LPG cylinder, a burner screwed directly onto the cylinder without a hose or regulator, and a locally made pot holder installed around the burner. It is designed to be used on the ground, in the yard or in the kitchen, and as such offers the same flexibility of use as most traditional charcoal stoves. Retail prices for a Telia stove in Ouagadougou range from USD 38.5 to 42[3]. The Telia stove was selected as the intervention technology for this study because of its relative affordability compared to other LPG stoves as well as its popularity among Burkinabe households and its good adaptation to local cooking practices.

Treatments

Some households will receive an offer to purchase a Telia stove from the study's partner distributor, Nafa Naana.

(1) Credit

The first treatment group will receive a stove purchase offer which will enable them to purchase the Telia kit either in cash or with a loan. If they choose the loan, the households will pay for their stoves in three monthly instalments and will be charged an administrative fee of XOF 3,500 (USD 5.5) or 14% of Nafa Naana’s official retail price for the Telia stove[4]. These financial terms mimic the payment terms offered by Nafa Naana to its customers in its day-to-day operations. Low demand for cost-effective products in Burkina Faso and in many other developing countries suggests that liquidity constraints often prevent poor households from adopting new technologies that could be cheaper to use or have very significant long-term individual benefits. This is the case for equipment that is much cheaper than gas stoves, such as impregnated bednets (Dupas 2014, Tarozzi et al. 2011). Several recent studies show that these financial barriers exist for cookstoves and that access to credit can be an effective tool to help households invest in equipment that requires a large initial investment but whose long-term benefits exceed their total cost (Berkouwer and Dean 2019, Levine et al. 2018). Studying the effect of access to credit on the use of gas in the Burkinabe context seems particularly relevant because a 50% subsidy on 6kg gas refills has been in place for several decades and makes the return on investment particularly attractive for households who used to buy their wood prior to adopting LPG[5].

[3] Price of a Télia kit including a burner, a 6 kg bottle and a pot holder.
[4] XOF 25,000 or USD 40.
[5] In Ouagadougou, a 6kg bottle of gas is sold for 2000 FCFA (or 3.3 USD) instead of 4000 FCFA.

Households assigned to the 'credit' group will also receive detailed written and verbal information about the total cost of the credit in order to avoid any effect of this treatment on gas uptake due to households' inattention to the cost of the credit (Berkouwer and Dean 2019). To distinguish the effect of credit from that of a strong present bias, we will use a series of questions included in the baseline questionnaire that aim to determine the rate of present preference of household heads and their wives.

(2) Subsidy

In the second treatment group, households will receive a stove offer with a price discount of XOF 9,500 (USD 15). This discount represents 38% of the market price of the gas stove. The discount covers the cost of the LPG burner and of the pot-rest which are supplied as part of the Telia kit. This implies that households assigned to this treatment group will only have to pay for the deposit which is applied for LPG cylinders in Burkina Faso and for the first refill which is sold with the Telia kit. Subsidizing the wear parts but not the cylinder is a relevant public policy option because subsidized cylinders tend to be subject to cross-border smuggling which can seriously disrupt LPG retail markets. While not currently in place in Burkina Faso, capital cost subsidies are a relevant policy option which has been tested successfully elsewhere (see above). They have the potential to address liquidity constraints problems while also increasing take-up among households with a low willingness-to-pay for modern cooking solutions.

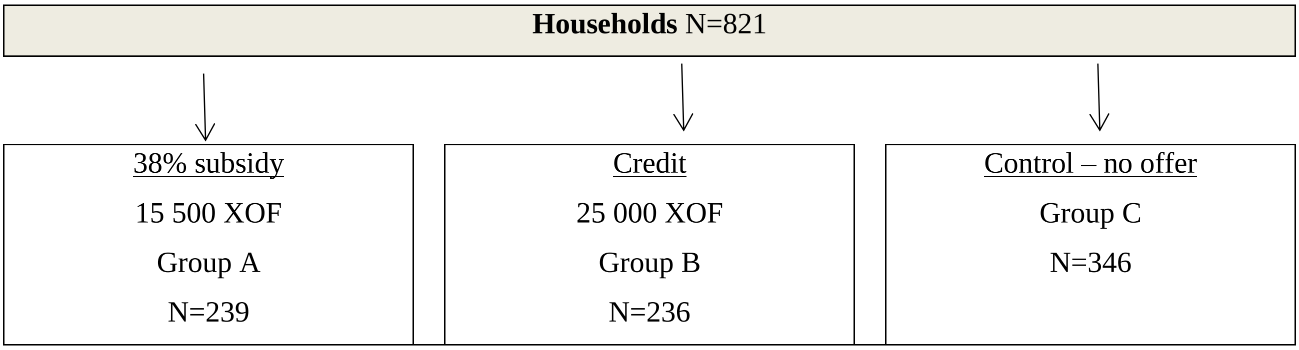
We will identify potential sunk cost effects and selection effects by comparing daily LPG usage rates and average daily use time among households assigned to credit, who pay the full product price, and among households assigned to the price discount. Anchoring and learning effects will be identified by comparing endline willingness-to-pay for LPG stoves in the control group and in each treatment group.

1.4 Assignment to treatments

Randomization for assignment to the experimental groups will be conducted at the household level. We will randomize in the laboratory in Spring 2022. Households in the sample will be randomly assigned with a 29% probability of being assigned to the credit group, 29% to the subsidy group and 42% to the pure control group. The treatment randomization strategy is presented in Figure 1 below.

The 'credit' and 'subsidy' treatments will take place at least three months after the second follow-up survey collected in December 2021 so that the two experiments do not overlap.

Figure 1: randomization strategy



2. Key data sources and research hypotheses

2.1. Key data sources

The primary sources of data are a baseline survey, two follow-up surveys and the endline survey. At most, households are observed four times during the project. Attrited households are replaced. Replacement households appear in the first or second follow-up surveys which constitute for them the baseline survey.

2.1.1 Baseline survey

The baseline survey took place after the sampling of households between December 2019 and February 2020.

2.1.2. Follow-up surveys

The follow-up surveys took place in June and July 2021 (first follow-up survey) and in December 2021 (second follow-up survey).

2.1.3. End-line survey

The end-line survey is planned to take place in October and November 2022.

2.1.4. Main modules of questions

Most questions are asked during these four rounds of survey as summarized in the table 1 below.

Table 1: Main modules of survey questions

Information	Baseline survey	Follow-up survey 1	Follow-up survey 2	End-line
Health - Self declared health	X		X	X
Health - Activities of Daily Living	X			X
Health - Anthropometric measures (weight, height) * for the children under 5 years old – # to be confirmed		X	X*	X*#
Health– blood pressure of all individuals over 14 years of age # to be confirmed		X		X#
Household characteristics (dwelling, ownership of durable goods) – updated if needed	X	X	X	X
Individual characteristics (education, work) – updated if needed	X	X	X	X
Individual's preferences for present	X		X	
Time use	X		X	X
Cooking habits	X	X	X	X
Fuel consumption	X	X		X
Air pollution in the city (9 points)		X		X
Air pollution for a household member in charge of the cooking activities	X	X		X
Willingness to pay for LPG stove				X
Beliefs about the cost of LPG use, about the consequences of wood consumption for health	X		X	X

Additional sources of data come from the retailer where the vouchers are redeemed and from the monitoring device of the SUMS as summarized in Table 2. Fieldworkers will closely work with the retailer to record any use of the offers by the households of the treatment groups. We will observe whether the offer is used and the date of purchase of the LPG stove as part of the experiment.

Table 2 - Variables of interest and corresponding data sources

	Ownership of a LPG stove	Frequency of LPG use	Daily LPG consumption	Share of LPG in useful energy consumed	24h Personal exposure to $PM_{2.5}$
Observation Unit	Household	Household	Household	Household	One household member in charge of cooking
Source of data	Purchase records, declarations and visual checks	Stove Usage Monitoring Systems (SUMS)	Kitchen Perf. Test (KPT)	Kitchen Perf. Test (KPT)	Gravimetric measurements (optical when gravimetric missing)
Number of data collection cycles	Four	Continuous (during 6 months)	Three	Three	Three
Schedule of measures	Baseline survey, 1st and 2nd follow-up surveys and endline	From stove purchase to endline survey	Baseline survey, 1st follow-up survey and endline	Baseline survey, 1st follow-up survey and endline	Baseline survey, 1st follow-up survey and endline
Measure unit	Indicator =1 if a stove is owned	Daily usage rate, average number of cooking events per day, average hours of use per day, average weekly/monthly usage frequency.	Average daily consumption in kilograms.	Average share of LPG in total useful energy consumed.	Average mass of particulate matter per cubic meter of inhaled air ($\mu g/m^3$).

2.2. Hypotheses

The interventions on access to gas will make it possible to test the following main hypotheses:

- Cash constraints lead households to make sub-optimal fuel choices from a health perspective. These constraints can be partly addressed through credit solutions or price reductions.
- Households who switch from wood or coal to gas as their primary energy source reduce their exposure to air pollution and thus have a reduced risk of developing air pollution-related diseases.

More precisely we have five sets of hypotheses to be tested summarized in Table 3 and detailed below.

Table 3: Hypothesis groups

A.	Impact of price and credit on LPG-adoption
B.	Impact of LPG-adoption on air pollution
C	Impact of LPG-adoption on other final outcomes
D.	Heterogeneity of the treatment effects
E.	Heterogeneity in the effects of LPG-adoption

The sets of hypotheses use the random assignment to measure causal effects.

***Hypothesis Group A*: Impact of price and credit on LPG-adoption -** *Receiving offers to purchase an LPG-stove with credit or with a discount may increase adoption (take up and usage) and also future willingness to pay for an LPG stove and the refills.*

Hypothesis A.1: Access to credit increases LPG uptake.

Hypothesis A.2: Subsidizing LPG-stove increases LPG uptake.

Hypothesis A.3: Credit and subsidy may have different impacts on take-up, intensity of use and WTP for LPG stoves. Variation in the price of the LPG stove, and in the choice given to buy it on credit, may generate a variety of impacts on the behaviour of households who adopt this technology:

- Intensity of use:
    - Screening: households who buy the stove at a relatively high price may have different motivations than those who buy it at a low price. It may then be expected than households who buy subsidized stoves have on average a low propensity to use the product.
    - Sunk costs: households who buy the stove at a relatively low price may value less their product and have a lower intensity of use.
    - Liquidity: continuous use of an LPG stove necessitates the regular purchase of LPG refills. Liquidity constrained households may have to delay the refill since gas cannot be bought in small quantities.
- Willingness to pay:
    - Anchorage: if households anchor their expectations with respect to future prices on current prices, then temporary subsidies may reduce future utility from purchasing these same products.
    - Learning: if households who buy the product learn about the benefits from using it, then subsidies, as they favour technology adoption, may increase future willingness to pay for the same product. The same holds for credit.

The following variables will form our set of outcomes for this hypotheses group:

- Ownership of a LPG stove;
- LPG stove sold or given away before endline survey;
- Declared frequency of use of a LPG stove;
- Observed frequency of use of the LPG stove (monitored by the SUMS: daily usage rate, number of cooking events per day, hours of use per day, weekly or monthly usage frequency);
- Daily consumption of LPG;
- Share of LPG in useful energy consumed by the household for cooking as measured by the Kitchen Performance Test at end-line;
- Beliefs about the cost and benefits of using LPG for cooking;
- Willingness-to-pay for LPG at endline.

As we may expect a difference in usage among the compliers according to the treatment, we will investigate the determinants of usage conditionally upon take up and unconditionally. In the former, the sample is the subsample of households who purchase the LPG stove as part of the experiment, while in the latter, the same is the entire sample of households. If conditional upon purchase, the households from the credit group are more likely to use the LPG stove than those from the discount group, this will suggest sunk cost effect.

<u>Hypothesis Group B</u>**: Impact of LPG-adoption on household air pollution** – *using a gas stove may reduce the household's exposure to air pollution*

The following variables will form our set of outcomes for this hypotheses group:

- Individual exposure to particulate measured during 24 consecutive hours;
- Categorical variable measuring individual exposure according to the US Environmental Protection Agency's Air Quality Index;
- Dummy variable recording unhealthy or very unhealthy exposure levels according to the US Environmental Protection Agency's Air Quality Index (equals 1 if exposure exceeds 150 $\mu g/m^3$ and 0 otherwise);
- Greenhouse gas emissions (we will use the fuel consumption data collected during the KPT and default emission factors published by the IPCC[6] to estimate differences in greenhouse gas emissions from cooking activities between the treatment and comparison groups[7]).

[6] See IPCC (2006). 'Guidelines for National Greenhouse Gas Inventories – Volume 2 – Energy. https://www.ipcc-nggip.iges.or.jp/public/2006gl/vol2.html. Accès le 11/7/2018.

[7] Additional data collection may be required to assess the fraction of non-renewable biomass (fNRB) in the study area before the proposed analysis of greenhouse gas emissions can be conducted. This would be the subject of a separate analysis paper

***Hypothesis Group C*: Impact of LPG-adoption on other final outcomes** – *using gas cookstove may reduce the household members' related diseases, increase time spent in income generating activities, increase time at school*

Hypothesis C.1: LPG-adoption leads to a decreased likelihood of suffering from pulmonary diseases through a decrease in exposure to air pollution.

The following variables will form our set of outcomes for this hypothesis:

- Wheezing or breathing difficulty;
- Irritation and inflammation of the airways (cough);
- Shortness of breath;
- Symptoms of acute respiratory infections (ARI),;
- Declared capability to conduct routine daily activities (measured by a series of dummy variables combined in an index);
- Self-assessed health;
- Health expenditures over the past 3 months;
- Medical consultations over the past 3 months;
- Hospitalizations over the past 3 months.

Hypothesis C.2: LPG-adoption leads to a change in time use

Cooking with LPG can be significantly faster and less messy than cooking with wood or charcoal. We aim to identify the potential effects of LPG on time spent cooking and other domestic tasks such as cleaning utensils among household members, particularly women and girls. Assuming that time is indeed saved, we will try to identify the activities to which this time is reallocated, for example by looking for effects on labor market participation or school attendance. We will therefore collect data on time spent on income-generating activities, domestic chores, and leisure for all household members as well as data on school enrolment and attendance for children and adolescents.

The following variables will form our set of outcomes for this hypothesis:

- School attendance;
- Time spent in household chores;
- Employment status;
- Hours of work per week.

from the main analysis of the study presented here, and the collection of data related to fNRB is therefore not discussed further in this protocol.

<u>Hypothesis Group D</u>**: Heterogeneity of the treatment effects on take-up, intensity of use and willingness to pay for LPG stoves –** *credit and subsidy may have heterogenous impacts on take-up, intensity of use and WTP for LPG stoves, while some characteristics of the respondents or the households before intervention may determine whether they differentially benefit from the interventions.*

<u>Hypothesis D1:</u> Treatment effects (credit and subsidy) may be heterogeneous according to the following dimensions:

- Commune of residence;
- Initial consumption of wood and charcoal;
- Initial level of exposure to $PM_{2.5}$;
- Characteristics of the household head and of his/her spouse (if any): education, gender, age, religion, ethnic group, present bias or time discounting factor, demand for LPG, attitude toward LPG and wood smoke, smoking status;
- Characteristics of the members in charge of cooking events: relationship with the household head (spouse, biological children, nephew, …), education, gender, age, religion, ethnic group, present bias or time discounting factor, demand for LPG at baseline, attitude and beliefs toward LPG and wood smoke at baseline, smoking status;
- Characteristics of the household members who take decisions regarding the purchase of cooking appliances: relationship with the household head (spouse, biological children, nephew, …), education, gender, age, religion, ethnic group, present bias or time discounting factor, demand for LPG, attitude toward LPG and wood smoke, smoking status;
- Household's size;
- Household's poverty score;
- Household's ability to save and value of household's savings (total, for all adults);
- Household head's ability to save and value of household head's savings;
- Spouse's ability to save and value of spouse's savings;
- Household's access to credit and household's level of indebtedness (and similarly for the household head and his spouse(s)).

<u>Hypothesis Group E</u>**: Heterogeneity in the effects of LPG adoption on exposure to $PM_{2.5}$ and other final outcomes -** *some characteristics of the respondents or the households may determine whether they differentially benefit from the LPG-adoption.*

<u>Hypothesis E.1</u>: We will examine whether the effects of LPG-adoption are heterogeneous according to the following dimensions:

- Dwelling has a closed kitchen;
- Time use of household members before intervention;

- Exposure to $PM_{2.5}$ at baseline;
- Wood consumption at baseline;
- Characteristics of the neighbours: proportion of closed kitchens in the neighbourhood, average wood consumption among neighbours, average exposure to $PM_{2.5}$ among neighbours;
- All the variables listed for hypothesis D.1 above.

3. Estimation methodology

Intention-to-treat (ITT) estimates

We will first conduct OLS regressions to produce intention-to-treat (ITT) estimates of the effects of interventions on each of the intermediate and final variables of interest. The basic econometric model used for the ITT estimates is the following:

$$Y_{ihc} = \beta_0 + \beta_1 C_{hc} + \beta_2 S_{hc} + \delta_c + \varepsilon_{ihc} \quad (1)$$

Where Y_{ihc} is the variable of interest for individual *i* in household h in commune c. C_{hc} and S_{hc} are indicator variables equal to 1 if the household was assigned to the 'credit' and 'subsidy' treatment respectively. δ_c is a commune fixed effect included in the model to account for the fact that randomization is stratified by commune. The analysis will be conducted at the household or individual level depending on the dependent variable of the model. A simplified version of this model will also be used to estimate the average effect of being assigned to a stove purchase offer:

$$Y_{ihc} = \beta_0 + \beta_1 T_{hc} + \delta_c + \varepsilon_{ihc} \quad (2)$$

Where T_{hc} is an indicator variable equal to 1 if the household was assigned to any of the treatments. Controls for baseline characteristics can also be added to these models. We will also control for the assignment to the treatment groups of the COVID19 experiment.

Estimation of the treatment-on-the-treated (TOT) effect

The analysis will also propose an estimation of the treatment-on-the-treated (TOT) effect of the incentive-type[8] interventions, i.e. the effect of the credit and price reductions on individual exposure to fine particles and on other outcomes via the acquisition of a gas stove. Indeed, since households who will choose to purchase a Telia kit are likely to have different unobservable characteristics than those who will choose not to subscribe to the offers, it is important to take into account unobservable characteristics in the analysis in order to obtain unbiased estimates

[8] These are designs in which interventions are designed to increase treatment uptake without 100% of the experimental units assigned to the treatment adopting it.

of the effect of the adoption and use of gas stoves on the final variables of interest. This will be done using an instrumental variable (IV) estimation strategy in which assignment to treatment will be used as an instrument for treatment adoption. In this specification the endogenous variable which is instrumented can be any variable measuring uptake or intensity of use of the stoves (LPG stove ownership or LPG consumption for instance).

The first stage equation of the instrumental-variable model can be written as follows:

$$A_{ihc} = \beta_0 + \beta_1 C_{hc} + \beta_2 S_{hc} + \delta_c + \varepsilon_{ihc} \quad (3)$$

Where A_{ihc} is a variable measuring LPG adoption. The predicted values of A are then used in the second stage equation of the model:

$$Y_{ihc} = \theta_0 + \theta_1 \hat{A}_{ihc} + \mu_{ihc} \quad (4)$$

Controls for baseline characteristics can also be added to these models along with the assignment to previous treatments related to the COVID19 experiment. A table of descriptive statistics by treatment status will also be published in order to deepen the analysis. In particular, it will include indicators of poverty as well as measures of the time discount rate of some key household members, in order to shed light on the mechanisms that might explain the effect of credit on LPG uptake, if such an effect is indeed observed.

Estimation of heterogeneous treatment effects

Heterogeneous treatment effects will be estimated either by running models (1) to (4) for specific sub-samples or by interacting treatment status in Equation (1) with the variable of interest Z (and all control variables in some cases).

To test Hypothesis D.1., the Equation (1) is extended as follows:

$$Y_{ihc} = \beta_0 + \beta_1 C_{hc} + \beta_2 S_{hc} + \beta_3 Z_{ihc} + \beta_4 C_{hc} * Z_{ihc} + \beta_5 S_{hc} * Z_{ihc} + \delta_c + \varepsilon_{ihc} \quad (5)$$

The variable of interest Z will in turn stand for the dimensions listed above and could be a binary variable (eg. The household having any level of education above primary) or a set of binary variables (eg. one for having a primary level of education, one for a secondary level, one for higher).

The same could be done with Equation (4) to test Hypothesis E.1.

Specific models to test hypotheses group B and C.

When possible and appropriate, we shall take advantage of the repeated observation of our dependent variables (see table 1) and estimate difference in difference models. The basic specification is given in Equation (6) below:

$$(6)\ \ Y_{ihct} = \beta_0 + \beta_1 C_{hc} + \beta_2 S_{hc} + \beta_3 X_{ihct} + \gamma_1 C_{hc} t + \gamma_2 S_{hc} t + \rho t + (\mu_h) + \delta_c + \varepsilon_{ihct}$$

With *t* the survey date and X_{ihct} a set of control variables. This equation will be estimated with OLS and with a fixed effect estimator to remove any bias resulting from potential constant household unobserved heterogeneity (μ_h). Since both treatments are randomly assigned and given that no household receives both treatments, estimated coefficients of the interaction terms, $\gamma_1$and γ_2, will provide ITT estimates of both treatment effects on the dependent variable. The difference in difference strategy will also the employed for estimating the impact on time varying variables of household LPG adoption, *A*. The estimated equation is then:

$$(7)\ \ Y_{ihct} = \beta_0 + \beta_1 A_{hc} + \beta_2 X_{ihct} + \gamma_1 A_{hc} t + \rho t + \mu_h + \varepsilon_{ihct}$$

With A_{hc} a dummy variable that equals 1 if the households adopted LPG for cooking at the endline survey. The intrahousehold version of this model only has time varying explanatory variables: X_{ihct} and $A_{hc}t$. As we cannot exclude that adoption may remain an endogenous variable, despite the wiping of the household fixed effect, we will also estimate the intrahousehold model with an instrumental variable estimator using treatment assignment as an instrument for A_{hc}.

Specific models to test hypotheses group A.

<u>Intensity of use:</u>

With intensity of use as the dependent variable, econometric models will take advantage of our continuous observation of LPG stove use over six months. The following specification will be estimated:

$$(8)\qquad U_{hc\tau} = \beta_0 + \sum_{H=1}^{n} \theta_H^C\, C_{hc} * 1_{\{H=\tau\}} + \vartheta_\tau + \delta_h + \varepsilon_{hct}$$

With τ the time period, during the 6 months of observation, over which LPG use, $U_{hc\tau}$, is measured. This could be a month, a week or even a day, as the sensors used to detect stove usage take a measure every two minutes. Measures are taken from the time of purchase to the end of the endline survey, 6 months later. The number of time periods, *n*, varies inversely with the length of the period, with a minimum of 6. The specification includes a household fixed effect, and the coefficients will be estimated either using OLS or a fixed effect estimator to hold account of any bias that could affect our estimates though treatment assignment is exogenous. The sample will be restricted to households who adopted the technology (since for other households the use of LPG is not observed). Three types of households will be observed in that subsample: those who bought the stove with a credit, those who bought the stove without credit but at a reduced price, and those who bought the stove at the market price without credit. This last set of households will all have been assigned to the credit treatment group. But the credit offer makes clear that the household may buy the stove at the market price and without credit. If a large enough number of households opt for this choice, we shall also estimate model (8) on the restricted sample of households made of the subsidy group and of those households.

In model (8), the estimated values of θ_H^C will inform about the potential impacts of screening or sunk cost effects, and liquidity constraints on stove usage. The model will be eventually supplemented with proxy variables of the household willingness to pay for LPG stoves, measured during one of the three surveys preceding treatment (interest in cooking with gas, perceived health threats related to wood combustion smoke) and with other household or individual characteristics to help identify screening effects.

Willingness to pay:

During the endline survey, all sampled households will be asked about their willingness to pay for an LPG stove. Those who already own one will be asked to evaluate the maximum price they would accept to pay for a new stove if they had to replace theirs. Model types that will be estimated are those shown in equations (1), (4) and (5), with eventually the pre-assignment proxy measures of the household willingness to pay for LPG mentioned in the previous section as supplementary explanatory variables. Estimated coefficients will help to identify anchorage and learning effects.

Cost effectiveness analysis

Cost effectiveness analysis will compare the two treatments. For each treatment, its costs will be compared to the following outcomes:

- Gain (equivalent in USD) in terms of air quality (decrease in the concentration of fine particles per mg) among the compliers and among the treated households;

- Gain in terms of number of cooking events in the population (that do not rely on wood or charcoal);

- Gain in terms of women's time use not devoted to cooking activities (number of hours);

- Gain in terms of women's participation to the labor market.

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