Pre-Analysis Plan:
A Comparison of Contests and Contracts to Deliver Cost-Effective Energy Conservation

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1 Introduction

1.1 Abstract

The energy sector in low- and middle-income countries is characterized by two stylized facts: (a) higher rates of particulate and carbon emissions per unit electricity generated and (b) low aggregate energy production and transmission losses resulting in lack of access and reliability of electricity. These concerns have led policy makers to encourage demand-side management through, for example, energy conservation programs in urban households such as tiered pricing, behavioral nudges, and direct "bonus" payments to keep energy use below a target maximum.

Urban energy conservation could help address the problem of grid balancing, that is reducing peak demand, especially as LMICs (including Vietnam where we are conducting our study) transition to a larger share of their electricity being generated from renewable resources. This is crucial to achieving the emissions reduction promise of renewable energy.

However, the issue of incentivizing agents (households) to exert costly, unobservable effort (energy abatement) is a long-standing and open question in economics. In many settings, including ours, the principal (utility) observes a performance measure (energy use) correlated with agent's effort but not the effort directly because the principal is unable to observe shocks beyond the control of the agent (e.g. weather, household demand shock). One possible solution is to use rank-ordered tournaments that incentivize relative performance, thereby obviating the need for the principal to observe common shocks. In this project, we draw on a rich theoretical and nascent empirical literature on contracts and rank-ordered tournaments to test aggregate conservation across contracts and contests and recover parameters that allow us to understand their effects at scale.

1.2 Motivation

- What is the main problem/question motivating the study?

  Climate change poses a threat to global well-being. An important pathway to mitigating climate change is through decarbonization of the electricity sector. Maximizing carbon savings from decarbonization requires effective demand-side management by, for example, motivating households to conserve energy. The aim of our study is to evaluate the effectiveness of different schemes that reward households for conserving energy. Specifically, our research question is: Are contests or contracts more effective in encouraging energy conservation among households?

- How has this problem/question been addressed thus far?

  The main problem is how to incentivize agents to conserve energy. Different incentive schemes have been proposed including individual contracts and behavioral nudges. Individual contracts reward households that reduce their monthly energy consumption, relative to their own past consumption, by a certain percentage. Behavioral nudges attempt to change household decisions by providing information. The effect of individual contracts and nudges has been studied in, for example, California Brandon et al. (2019). Also, Chen et al. (2021) study how contest work in a teamwork setting.

- How is this study different from prior research on this problem/question?

  A contest is an alternative scheme where rewards are awarded based on *relative* performance. Prior research has studied the effect of contests on performance in different settings (Knoeber and Thurman, 1994; Chen et al., 2021). Our setting is different and leverages the opportunity to enroll a large number of households receiving sizeable monetary rewards. Moreover, we are interested in investigating how the *design* of contests and contract impacts performance. For this purpose, we will use our experimental data to estimate a structural model, which separates our study from previous research.

  We make important contributions to the empirical literature on tournaments. Specifically, we provide new evidence on two classic questions in the tournaments literature. The first is whether tournaments dominate contracts (Lazear and Rosen, 1981; Green and Stokey, 1983) and the second is the optimal contest size (Taylor, 1995). In particular, we will provide new evidence on these questions considering the cases in which participants will and will not receive performance feedback (about their own performance and that of all players in the competition). Prior work has shown that performance feedback can impact incentives in tournaments, which motivates us to study whether the answer to these classic questions depend on the information design (Lemus and Marshall, 2021). A strength of our analysis will be that the tournament designs faced by participants will be randomly assigned and we observe a high-frequency performance measure (i.e., energy use) before, during, and after the competitions. Importantly, relative to prior work, we provide a large-scale field experiment in a typical major urban metropolitian city in an LMIC generating externally valid results.

  Another contribution is that we will leverage our high-quality energy use data to make inferences about the investments made by households during the tournament. By comparing energy use before, during, and after, across households assigned to different tournament designs (e.g., longer contests with performance feedback versus short contests without feedback), we can shed light on which tournament design incentivizes the adoption of energy-saving strategies that lead to energy savings beyond the end of the tournament

- Why is the context that you have chosen for this study appropriate?

  Our research team has developed a relationship with Hanoi City Power Corporation (EVNHANOI). This collaboration has made it possible for us to recruit thousands of households to participate in our competitions. Furthermore, the contest platform is fully integrated into the app households use to view their energy consumption.

1.3 Research Questions

- What are the main research questions the study seeks to answer?

In this project, we ask three questions. First, what is the cost effectiveness of contests relative to contracts in reducing energy conservation when contracts are incomplete because household's abatement effort and costs are unobservable to the utility. Second, do these effects persist over time and after the end of the contest/contract period? Third, how can these programs be scaled in a cost-effective and fiscally feasible manner in LMICs? Our project will not only inform the design of energy conservation policies in Vietnam and the efficiency in incentivizing behavior to manage demand, but also provide us with the cost-effectiveness of various energy conservation programs and consequently a menu of costs per metric ton of CO2 abated.

2 Research Strategy

2.1 Sampling

2.1.1 Sampling Frame

- What is the eligible population for the study? What are the main characteristics of this population?

  Our target population will be households in Hanoi, the capital and the second largest city of Vietnam. With rapid economic growth since the Vietnamese economic reform started in 1986, the city has seen many Hanoians moving out of poverty and into the middle class. Many households can now afford new televisions, refrigerators, or air-conditioners for the first time. The city's hot and humid weather also spurs demand for new and heavy use of air conditioners. Those trends in energy consumption put the city at the top of the nation in terms of electricity consumption per person. At the same time, Hanoi (and the rest of Vietnam) also faces energy constraints that manifest into rolling blackouts and intermittent electricity access. In these respects, Hanoi is well representative of urban populations where energy use is expected to dramatically increase over the next three decades.

- What is the expected sample for the study?

  The electric utility in Hanoi, EVN HANOI, has over 2.8 million customers, and 90% of them have smart meters. About 25% of all households in Hanoi have installed the utility's app. Through our partnership with the utility and the utility app's developer, we will advertise the program through different channels, including the utility's official website, and fan pages, banners and ads in the utility's app, and offline marketing. Given our marketing budget, we expect about 15,000 households to sign up for the program.

- How does the expected sample differ from the population?

  Since we primarily advertise the program via banners and ads in the utility's app, the majority of our sample for this initial study will include households that already have downloaded the utility's app for tracking energy use and making bill payments. The app was released in 2019 with rollout delayed due to the COVID-19 pandemic.

2.1.2 Statistical Power

To choose the sample size of our study, we use data from our pilot study from December 2022 to January 2023. We then use the following equation to calculate the appropriate sample size for our study:

$$J = \frac{\left(t_{1-\kappa} + t_{\frac{\alpha}{2}}\right)^2}{P\left(1-P\right)} \frac{\sigma^2}{MDE^2} \left(\rho + \frac{1-\rho}{T}\right)$$

where

- J is the sample size
- κ is the probability of correctly rejecting a false null or the power
- α is the probability of a type I error
- $t_{\frac{\alpha}{2}}$ and $t_{1-\kappa}$ are the critical values of t distributions
- MDE or the mean detectable effect is the smallest effect size where an effect can still be detected if there is one
- P is the proportion of the sample that is treated
- σ^2 is the variance of the treatment effect estimator
- ρ is the intracluster correlation coefficient
- T is the length of the experiment in days

We set κ to 0.80, or 80%, and α to 0.05, or 5%, values typically used for these calculations. The proportion of the sample that is treated is 50%. We use the pilot data to calculate the variance of the outcome variable and intraclass correlation coefficient $\rho = 0.566$. For sensitivity, we vary σ from 0.05 to 0.5. For the low variance $\sigma^2 = 0.05$, to detect $MDE = 1.5\%$ the required sample size of each treatment and control group is $2,672$. For the high variance $\sigma^2 = 0.5$, to detect $MDE = 3\%$ the required sample size of each treatment and control group is $3,338$.

2.1.3 Assignment to Treatment

- How will individuals be assigned to treatment and control conditions?

  Individuals will be randomly assigned to treatments and control conditions.

- What is the source of exogenous variation in your study?

The research team will randomize each household in one of four groups, three treatment groups and one control group. Two treatment groups will be assigned to contracts, with each group differing in the thresholds of energy savings they must reach to win a price. The third treatment group will be assigned to contests. The duration of treatments is 30 days from mid-July to mid-August. The control group will not be assigned contest or contract participation. Participants can use their smart meters to monitor their progress by default, so all households, including the control group, will receive information about their past and current daily electricity use on the electric utility company's app.

The groups will be as follows:

- Treatment 1, Contract with low thresholds. This group will receive $4.35 USD if they conserve 5% of electricity compared to their average daily energy use in July and August last year, $6.52 if they conserve 10% and $10.87 if they conserve 15%. This group will also receive weekly text message reminders, saying "There are [insert number] days left in the contract which ends on [insert end date]. Check the app to see your energy savings."

- Treatment 2, Contract with high thresholds. This group will receive $6.52 USD if they conserve 10% of electricity compared to their average daily energy use in July and August last year, $10.87 if they conserve 15% and $15.22 if they conserve 20%. This group will also receive weekly text message reminders, saying "There are [insert number] days left in the contract which ends on [insert end date]. Check the app to see your energy savings."

- Treatment 3, Contest. This group will compete in groups of about 50 households in energy conservation. Of every 50 households, only the household that conserves the most energy, compared to their average daily energy use in July and August of the previous year, will receive a prize of $87. This group will also receive weekly text message reminders, saying "There are [insert number] days left in the contest which ends on [insert end date]. Check the app to see your energy savings."

- Control group, No contest or contract participation. This group will not be participating in either contract or the contest. This group will receive weekly text message reminders, saying: "Please check the app to see your energy savings."[1]

Among households who register for the study, we will restrict the set of households as follows to generate the final list of participants:

- Keep households with less than 20 percent of missing daily energy consumption information in the period between July 2022 and May 2023.

- Keep households with less than 10 percent of missing daily energy consumption information in the period between July 15, 2022 and August 13, 2022 (i.e., the comparison period for the experimental period).

- Keep households with less than 20 percent of daily energy consumption observations equal to zero (i.e., zero consumption) in the period between July 2022 and May 2023.

- Using the distribution of the average daily consumption at the household level between July 2022 and May 2023, we will drop households with average daily consumptions that exceed the 95th percentile of the distribution or are less than the 5th percentile of the distribution.

[1] To avoid dissatisfaction and exclusion, we agreed to pay out a small amount of about $0.40 USD to participants selected in the control group and thank them for enrolling in the program after the program ends.

- Using the distribution of the average daily consumption at the household level in the period between July 15, 2022 and August 13, 2022, we will drop households with average daily consumptions that exceed the 95th percentile of the distribution or are less than the 5th percentile of the distribution.
- We will drop households with at least one day with a negative electricity consumption or with a consumption greater than 100 kWh.

Households assigned to the contest treatment will be sorted into groups based on their average consumption in the period between July 15, 2022 and August 13, 2022 (i.e., the comparison period for the experimental period) to ensure that contest participants are competing with households that are similar in energy consumption.

2.1.4 Attrition from the Sample

- Do you anticipate any form of attrition from the sample?

  Attrition may occur if participants move out of Hanoi, or if they voluntarily choose to leave the study and request that the electricity utility stop sharing their energy usage with the research team. However, we anticipate this to be unlikely. The study carries no cost for the households that choose to remain in it. Instead of leaving the study, households can simply choose to stop making an effort to conserve energy. These reductions in effort are not considered attrition, but rather, the outcome we are interested in studying.

2.2 Fieldwork

2.2.1 Instruments

- What data collections instruments will you employ?

  We will use smart meter data.

2.2.2 Data Collection

- How long will the entire data collection process take from start to finish?

  The contests will last 1 month but we will continue to collect electricity consumption data until at least 1 year after the contests have ended.

- What does the data collection entail?

  We will be receiving electricity consumption data from the utility.

- What steps will be take to keep the data collected confidential at this stage?

  Data will be anonymized before we conduct analysis. Each consumer will be given a random unique ID.

2.2.3 Data Processing

- What does the data processing entail?

  The first step is to randomly place participants in one of the 4 groups. We will have to check if these groups are properly balanced (see discussion below).

  The analysis will include conducting the balance checks and running the regressions to evaluate the treatment effects, as described below.

- What steps will be take to keep the processed data confidential?

  All analysis will be conducted with random unique IDs rather than any identifying information.

- Who has ownership over the processed data?

  The research team will have ownership over the processed data.

- How will the data be used/stored after the study at this stage?

  The data will be stored in the research team's Dropbox and potentially used again to inform another similar study.

3 Empirical Analysis

3.1 Variables

The main variable of interest is daily electricity consumption at the household level. This variable is obtained from the utility company, which measures electricity consumption with smart meters installed in every home. We will obtain daily electricity consumption at the household level during the length of the competitions and contracts. We will continue to collect this information until at least twelve months after the end of the experiment.

Due to measurement issues, the daily consumption of some households may not be recorded. We will need to drop the household–day combinations in which this occurs.

3.2 Balance Checks

We will check balance between the treatment and control groups using data on the historical electricity use of households. Specifically, we will use the monthly electricity use of every household in the previous 12 months in our balance checks.[2]

For each of these variables, we will run the following specification:

$$y_i = \alpha + \sum_k 1\{\text{treatment}_i = k\}\beta_k + \varepsilon_i,$$

where treatment_i is a variable indicating the treatment assignment of household i. The regression includes indicators for all treatment groups except for the control group (the

[2] We plan to use daily data for at least for 3 months prior to the interventions, unless data are not available.

omitted category). In our balance analysis, we will report estimates for the coefficients $\{\beta_k\}$, their standard errors, and the p-value from a joint test of statistical significance of all coefficients on the treatments indicators (i.e., a test where $H_0 : \beta_1 = \beta_2 = \cdots = \beta_K = 0$) for every variable listed above.

We will complement these mean comparison tests with Kolmogorov-Smirnov equality-of-distribution tests for each covariate that is a continuous variable (e.g., electricity consumption). In these tests, we compare the distribution of a variable in a given treatment group with that of the control group. The null hypothesis is that the distributions are equal.

3.3 Treatment Effects

3.3.1 Treatment on the Treated

In our study, participants must opt in. Among the participants who join the study, we randomize treatment assignments. We thus focus on estimating treatment on the treated effects.

To measure these treatment effects, we will run the following regression:

$$y_i = \alpha + \sum_k 1\{\text{treatment}_i = k\}\beta_k + X_i'\delta + \varepsilon_i, \tag{1}$$

where y_i is the overall electricity consumption or average daily consumption during the study period, X_i is a set of covariates (one specification will include no covariates, another specification will include the covariates used in the balance analysis), and ε_i is an error term.

We will repeat this analysis using data that extends beyond the end of the study period. Specifically, we will use data on the electricity use of households during the month-long study period as well as during the months after the study period concluded to measure whether the treatments caused energy savings that extend beyond the treatment period. Specifically, we will run the following regressions:

$$y_{i,t} = \alpha + \sum_k \sum_t 1\{\text{treatment}_i = k\}1\{t = \tau\}\beta_{k,\tau} + X_i'\delta + \varepsilon_{it}, \tag{2}$$

where $y_{i,t}$ is energy use $t \in \{0, 1, 2, \cdots, \bar{T}\}$ months after the beginning of the study, and $\beta_{k,\tau}$ measures the average impact of treatment k on electricity consumption τ months after the beginning of the study (where the control group is the excluded category), and ε_{it} is an error term clustered at the household level.

As well, we will exploit the within-household variation in incentives to conserve energy and run an analysis that resembles equation (2), but that uses data that precedes the start of the experiment.

$$y_{i,t} = \alpha + \sum_k \sum_t 1\{\text{treatment}_i = k\}1\{t = \tau\}\beta_{k,\tau} + X_i'\delta + \varepsilon_{it}, \tag{3}$$

where $y_{i,t}$ is energy use $t \in \{-\bar{T}, -\bar{T}-1, \ldots, 0, 1, \ldots, \bar{T}\}$ months relative to the beginning of the study, and $\beta_{k,\tau}$ measures the average impact of treatment k on electricity consumption τ months relative to the beginning of the study (where the control group is the excluded category), and ε_{it} is an error term clustered at the household level. Given the within-household variation in incentives to conserve energy, equation (3) may include household fixed effects.

Equation (1) makes use of energy consumption during the length of the experiment. Equations (2) and (3) may use monthly consumption data or daily consumption data. All models may be used using energy consumption in levels or in logs. When using daily consumption data, we drop observations for which energy consumption is not recorded.

3.4 Heterogeneous Effects

We will investigate heterogeneous effects based on historical electricity consumption. The objective is to identify the households where the program most effectively induces energy savings.

Consider a covariate Z_i (e.g., past monthly electricity consumption) that has been demeaned (i.e., the mean value of Z_i is zero). To measure heterogeneous treatment effects, we will run the following regression:

$$y_i = \alpha + \sum_k 1\{\text{treatment}_i = k\}\beta_{1,k} + \sum_k 1\{\text{treatment}_i = k\}Z_i\beta_{2,k} + X_i'\delta + \varepsilon_i,$$

where y_i is electricity consumption during the study period (i.e., overall electricity consumption or average daily consumption), X_i is a set of covariates that includes Z_i, and ε_i is an error term.

In this model, the effect of treatment k on the treated, given Z, is $\beta_{1,k} + \beta_{2,k}Z$. Since Z is demeaned, the average effect of treatment k on the treated is simply β_k^1.

3.5 Standard Error Adjustments

Randomization will be at the household level. We will cluster standard errors at that level.

4 Model-based Analysis of a Household's Energy Consumption

A household observes some covariates (e.g. month, past month weather) which determines its *baseline* consumption, $e^\eta > 0$. The household can reduce or increase this baseline consumption by choosing a *comfort* level, $z \geq 0$. Higher levels of comfort level require more energy use. The household chooses an expected consumption (in kWh), which is the baseline consumption level scaled by the comfort level, ze^η. The household's actual consumption is subject to an unanticipated random shock, e^ε, so the consumption measured by the econometrician is

$$\hat{z} = ze^{\eta+\varepsilon},$$

where $\varepsilon \sim F$ with $E[\varepsilon] = 0$.

The household enjoys higher levels of comfort but dislikes paying for energy. The payoff of a household that chooses a comfort level z when the cost of (1 kWh) of energy is μ is

$$c(z) \equiv u(z) - \mu z e^{\eta} E[e^{\varepsilon}] \tag{4}$$

where $u(z)$ is increasing and strictly concave.

4.1 Contracts

Consider a contract with three consumption-reduction thresholds, L_1, L_2 and L_3, awarding three prizes V_1, V_2, and V_3, where $L_1 < L_2 < L_3$ and $V_1 < V_2 < V_3$. A household actual consumption (in kWh) is $\hat{z} = ze^{\eta+\varepsilon}$. The energy *reduction*, r, by a household with past consumption $\hat{z}^{past}$(in kWh) is

$$r = 1 - \frac{\hat{z}}{\hat{z}^{past}}.$$

The contract specifies the following terms: If $r \leq L_1$ the household wins nothing; If $L_1 < r \leq L_2$, the household wins prize V_1; if $L_2 < r \leq L_3$, the household wins prize V_2; and if $L_3 < r$, the household wins prize V_3.

For example, if V_3 is awarded for a reduction larger than L_3 percent, which is equivalent to

$$1 - \frac{\hat{z}}{\hat{z}^{past}} > L_3 \quad \Leftrightarrow \quad \frac{\hat{z}}{\hat{z}^{past}} < 1 - L_3 \quad \Leftrightarrow \quad \log(\hat{z}) < \log(z^{past}) + \log(1 - L_3)$$

We define $y = \log(\hat{z}) = \log(z) + \eta + \varepsilon$, $x = \log(z)$, $y^{past} = \log(\hat{z}^{past})$, and the thresholds in logs, $\ell_i = \log(1 - L_i)$. Note that $\ell_1 > \ell_2 > \ell_3$. Hence, the household receives prize V_3 if

$$y < y^{past} + \ell_3.$$

The household chooses a comfort level z, equivalently, $x = \log(z)$ by solving

$$\max_{x \geq 0} V_1 P(\ell_1 + y^{past} \geq y > \ell_2 + y^{past}) + V_2 P(\ell_2 + y^{past} \geq y > \ell_3 + y^{past}) + V_3 P(\ell_3 + y^{past} \geq y) + c(e^x),$$

where $c(\cdot)$ is defined in (4).

Assuming that the distribution F does not have mass points, the problem is equivalent to

$$\begin{aligned} &\max_{x \geq 0} V_1(F(\ell_1 + y^{past} - \eta - x) - F(\ell_2 + y^{past} - \eta - x)) \\ &+ V_2(F(\ell_2 + y^{past} - \eta - x) - F(\ell_3 + y^{past} - \eta - x)) + V_3 F(\ell_3 + y^{past} - \eta - x) + c(e^x) \end{aligned}$$

Taking FOC we obtain

$$\begin{aligned} V_1 f(\ell_1 + y^{past} - \eta - x^*) + (V_2 - V_1) f(\ell_2 + y^{past} - \eta - x^*) + ... \\ ... + (V_3 - V_2) f(\ell_3 + y^{past} - \eta - x^*) + \mu z e^{\eta} E[e^{\varepsilon}] e^{x^*} = u'(e^{x^*}) e^{x^*} \end{aligned} \tag{5}$$

4.2 Contest

Suppose there are N agents competing in a static contest. Agents exert costly effort to reduce their energy consumption, and the household with the largest reduction wins the contest. We use the same notation as before: A household chooses expected consumption and its actual consumption (in logs) is

$$y = x + \eta + \varepsilon.$$

Agents are ranked according to their reduction (from the largest reduction to the lowest one), where energy reduction is given by $y - y^{past}$ (difference in log consumption). With a single prize, V, agent i wins the contest if

$$y_i - y_i^{past} < y_j - y_j^{past} \text{ for all } j \neq i.$$

This expression is the same as

$$x_i + \varepsilon_i - y_i^{past} < x_j + \varepsilon_j - y_j^{past} \Leftrightarrow x_i - x_j + y_j^{past} - y_i^{past} + \varepsilon_i < \varepsilon_j.$$

Note that the common baseline consumption, η, does not alter the agents' ranking. This means that the incentives to save energy in the contest are unaffected by η.

Let us consider a symmetric equilibrium, where $y_i^{past} = y^{past}$ for all i, and each agent optimally chooses $x_i = x^*$. Fixing ε_i, player i wins with probability

$$\psi(x_i, \varepsilon_i, x^*) \equiv (1 - F(x_i + \varepsilon_i - x^*))^{N-1}.$$

Player i chooses her effort before knowing the realization of the shock ε_i. Then, the optimal choice of x_i solves

$$\max_{x_i \geq 0} V \int \psi(x_i, \varepsilon_i, x^*) f(\varepsilon_i) d\varepsilon_i + c(e_i^x).$$

The FOC is

$$V \int \frac{\partial \psi(x_i, \varepsilon_i, x^*)}{\partial x_i} f(\varepsilon_i) d\varepsilon_i + \mu z e^{\eta} E[e^{\varepsilon}] e^{x^*} = u'(e^{x^*}) e^{x^*}.$$

In a symmetric equilibrium we must have $x_i = x^*$. Thus, we can solve for x^* explicitly by solving the equation

$$V \int (N-1)(1 - F(\varepsilon_i))^{N-2} f^2(\varepsilon_i) d\varepsilon_i + \mu z e^{\eta} E[e^{\varepsilon}] e^{x^*} = u'(e^{x^*}) e^{x^*}. \tag{6}$$

4.3 Control Group

Consider a household assigned to the control group (i.e., no incentives offered). The household actual consumption (in logs) is $y = x + \eta + \varepsilon$. The household chooses a comfort level z to maximize (4), which is equivalent to

$$\max_{x \geq 0} u(e^x) - \mu e^x e^{\eta} E[e^{\varepsilon}].$$

This problem simply captures a tradeoff between comfort and energy consumption. Assuming that an interior solution exists, the FOC of the problem is

$$u'(e^x) = \mu e^{\eta} E[e^{\varepsilon}]. \tag{7}$$

4.4 Estimation

In the empirical analysis, each household is one of K types, each type denoted by $\kappa = 1, ..., K$. Let N_κ be the number of households of type κ.

We allow for the value of comfort to vary by type, $u_\kappa(z)$. For instance, $u_\kappa(z) = \gamma_\kappa z^\alpha$. We can define the cost function by

$$c_\kappa(z) = \mu z e^\eta E[e^\varepsilon] - u_\kappa(z).$$

We can assume a functional form for the distribution of shocks F, e.g., $N(0, \sigma^2)$, which is common across types.

In our experiment, we will have households of type κ assigned to four treatment conditions: control, contract I, contract II, and contest.

Fixing a set of parameters $\Theta_\kappa = [\sigma, \alpha_\kappa, \gamma_\kappa, \eta_\kappa]$, for each household type:

1. Given a set of parameters Θ_κ, we solve the problem of type-κ households in every treatment condition. From (5), (6), and (7), we obtain the values of the expected consumption of the household $x^*_{\text{contract I},\kappa}(\Theta_\kappa)$, $x^*_{\text{contract II},\kappa}(\Theta_\kappa)$, $x^*_{\text{contest},\kappa}(\Theta_\kappa)$, and $x^*_{\text{control},\kappa}(\Theta_\kappa)$.

2. Using Θ_κ and $x^*_{\text{control},\kappa}(\Theta)$, $x^*_{\text{contract I},\kappa}(\Theta)$, $x^*_{\text{contract II},\kappa}(\Theta)$, and $x^*_{\text{contest},\kappa}(\Theta)$, we compute the expected consumption (in logs) predicted by the model, which is

$$E[y^{j,\kappa,model}] = x^*_{j,\kappa}(\Theta_\kappa) + \eta_\kappa,$$

   for $j \in \{$control, contract I, contract II, contest$\}$.

3. We compare the consumption predicted by the model with that in the data by forming moments

$$m^{j,\kappa}(\Theta_\kappa) = E[y^{j,\kappa,model}] - \sum_{i \in N_{j,\kappa}} y_i^{j,\kappa,data},$$

   where $N_{j,\kappa}$ are households of type κ assigned to treatment j and $y_i^{j,\kappa,data}$ is the observed consumption of household i of type κ assigned to treatment j. At the true parameters Θ_0, we have that $m^{j,\kappa}(\Theta_0) = 0$.

4. Lastly, we find the vector of parameters Θ that minimizes the value of the GMM objective function

$$\hat{\Theta} = \arg\min m(\Theta)' \Sigma m(\Theta),$$

   where $m(\Theta)$ is the vector that stacks all moments $m^{j,\kappa}(\Theta)$ and Σ is a positive-definite weight matrix. $m(\Theta)$ is of dimension $4 \cdot K$ where 4 is the number of treatment conditions in our experiment and K the number of types — this number provides the upper bound on the number of parameters that we can identify.

Note that variation in the incentive schemes provides us with additional moments that provide us with the ability to identify the parameters of the model.

4.5 Counterfactual

Given estimates of the model, we can simulate outcomes for every household under arbitrary contracts or contest rules. The following is a possible set of counterfactuals:

- Given a per-household budget, b, and a fixed number of prizes, m, we can compute the thresholds and prizes, $(L_i, V_i)_{i=1}^m$, that maximize energy savings.

  To this end, we first use the estimated parameters, $\widetilde{\Theta}_\kappa$, to compute $x^*(\widetilde{\Theta}_\kappa|(L_i, V_i)_{i=1}^m)$ from (5). Then, we solve
  $$\min_{(L_i,V_i)_{i=1}^m} x^*(\widetilde{\Theta}_\kappa|(L_i, V_i)_{i=1}^m)$$
  A more flexible approach can determine type-dependent thresholds and prizes. The energy saving for one household given optimal threshold and prizes is $x^*(b)$. With a total budget of B, the "optimal" contract can be implemented for B/b households. So, the optimal budget splitting (ignoring integer constraints) solves

  $$\min_b \frac{B}{b} \cdot x^*(b)$$

  Suppose the solution to the problem above is b^* and define $N(B) \equiv B/b^*$.

- We can compare the performance of this optimal contract for $N(B)$ households with a contest that allocates a budget of B to $N(B)$ households. The budget allocation can entail a single prize, or more complex prize structures.

The results of these comparisons depend on the value of the common shock, η. We will repeat these comparisons for alternative values of η, as a sensitivity check.

5 Research Team

- Who are the principal investigators of this study?

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- Will there be any research assistants in this study?

  Yes, there is one research assistant, Biz Yoder.

  - If so, what will these research assistants do?

    The research assistant will be in charge of data analysis.

References

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Amendment to Pre-Analysis Plan: A Comparison of Contests and Contracts to Deliver Cost-Effective Energy Conservation

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The selection criteria for the main study left about 2,000 households that we would consider second pick. With these households, we will run a contest scalability experiment where 700 households (HHs) are assigned to a contest with 20 households (treatment 1), 700 households are assigned to a contest with 50 households (treatment 2), and 628 households are the control group.

- Treatment 1 is contests with 20 participants, 700 HHs
- Treatment 2 is contests with 50 participants, 700 HHs
- Treatment 3 is control group, 628 HHs

Contest number is sorted based on past consumption, just as in the main study. We will run the specifications that we pre-registered in the Pre-Analysis Plan for the main study.

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