Pre-Analysis Plan for Nutritious Food without Fire

1. Introduction

In rural sub-Saharan African (SSA), many households rely on firewood and/or charcoal as the main sources of energy for cooking. Increasing population pressure in many parts of SSA is having a large impact on deforestation and, by extension, human health. As the forested landscape around human habitats is reduced (e.g. in Zambia, 0.2% of the land was deforested in a yearly basis between 2001-2014 - Hansen et al. 2013), the cost of procuring energy for cooking increases. The opportunity cost of finding firewood increases as household members must venture further and further from habited areas to find wood. This in turn increases the monetary cost of purchasing charcoal. As the price of energy inputs to preparing a meal rise the ability of households to incorporate healthy cooking habits falls. With high energy costs, households are less likely to boil water and milk, increasing susceptibility to water and milk borne diseases. Additionally, dietary diversity decreases as households refrain from preparing slow-cooking foods, like legumes, and instead focus on a small number of quick cooking foods such as corn meal.

In order to investigate the link between rising fuel costs for cooking and poor nutritional outcomes we will conduct a solar stove field experiment in the Barotse region of western Zambia. We will examine the impact of solar cookers which are randomly assigned to households across several communities. We will document the effects of the cookers on both the costs of preparing food and the types of food that the household prepares. Households will record the ingredients used in preparing each dish for each meal on each day plus the fuel used to prepare each dish over the six weeks of the experiment. This will provide us with detailed information on food and fuel inputs that each household used in preparing an expected 126 meals (3 meals a day * 7 days * 6 weeks) consumed over the study period.

Barotseland, the area of our intervention, has seen extensive work in the context of the CGIAR Research Program – (CRP) Aquatic Agricultural Systems (AAS) where

Bioversity International and World Fish to promoted nutritional information as well as crop diversification strategies for resilient and productive farming systems. Households in the region have self-selected into nutritional cooking clubs, participation in farm plot demonstrations, or chosen to abstain from participation in these development activities. We will stratify our randomization across these four groups in order to help us understand which information, from which activity might have a larger impact on shifting people towards more diverse diets, particularly when there is access to a low cost source of energy for cooking.

The research questions are as follows:

1) To what extent the provisioning of solar stoves reduce the amount of fuel (firewood, charcoal, dung) used by the household to cook meals?
2) Does the provisioning of solar stoves change the composition of the diet (measured by household dietary diversity, dietary species richness, count of the number of dishes, and count of the number of meals skipped) eaten by the household?
3) To what extent the provisioning of solar stoves increase the amount of liquid (water or milk) that is boiled by the household?
4) Does the provisioning of solar stoves increase the amount of legumes consumed by the household?
5) Does the use of solar stoves to cook some dishes affect the composition of other dishes cooked by the household using traditional stoves?
6) Are there heterogeneous effects based on self-selection into participation in cooking demonstrations, participation in agricultural demonstrations, or both?

Five main assumptions are behind our theory of change. The first assumption is that deforestation on the Barotse floodplain has increased the cost of traditional cooking fuel (firewood and charcoal) to the point where the price of cooking fuel is a binding constraint on the household's decision regarding what meals to prepare. The second assumption is that households with a solar stove will reduce their use of traditional cooking fuel, thus reducing their costs of meal preparation. The third assumption is that, with a reduction in fuel costs, households will prepare more healthy meals. This includes preparing meals that include more ingredients, preparing meals that result in greater dietary diversity, boiling more liquids, and cooking more legumes. The fourth assumption is that, conditional on a reduction in fuel costs, households will change the composition of dishes cooked using traditional fuel as they re-optimize over their consumption decisions. The fifth assumption is that these effects will differ for households that had previously self-selected into participating in nutrition and/or farming demonstrations compared to households that self-selected to not participate.

2. Outcomes

a. Intermediate outcomes

The intermediate outcomes of the intervention is the take-up of the solar stove, which we measure of two ways:

1. An indicator equal to 1 if a solar stove was used to prepare a given dish, boil a given quantity of liquid, or cook a given quantity of legumes, and zero otherwise.
2. The share of all dishes (alt: liquids, legumes) prepared using a solar stove during a given timeframe, such that $share_{ht} = \frac{\sum_{d=1}^{D} solar\ stove\ use}{\sum_{d=1}^{D} all\ fuel\ use}$, where h

indicates the household, *t* indicates the time frame, *d* is an individual dish (alt: liquids, legumes), and *D* is the total number of dishes (alt: liquids, legumes) prepared during the time frame.

b. Final outcomes

The expected final outcomes of the study are organized in five broad measures:

1. Fuel use
    - Firewood
        1. The time spent collecting firewood in each week
        2. The time spent collecting firewood over all six weeks.
        3. The money spent purchasing firewood in each week.
        4. The money spent purchasing firewood over all six.
        5. The amount of firewood that was collected in each week.
        6. The amount of firewood that was collected over all six weeks.
    - Charcoal
        1. The time spent collecting charcoal in each week
        2. The time spent collecting charcoal over all six weeks.
        3. The money spent purchasing charcoal in each week.
        4. The money spent purchasing charcoal over all six.
        5. The amount of charcoal that was collected in each week.
        6. The amount of charcoal that was collected over all six weeks.
    - Dung
        1. The time spent collecting dung in each week
        2. The time spent collecting dung over all six weeks.
        3. The money spent purchasing dung in each week.
        4. The money spent purchasing dung over all six.
        5. The amount of dung that was collected in each week.
        6. The amount of dung that was collected over all six weeks.
    - All fuel
        1. The time spent collecting fuel in each week
        2. The time spent collecting fuel over all six weeks.
        3. The money spent purchasing fuel in each week.
        4. The money spent purchasing fuel over all six.
2. Composition of diet
    - Dietary diversity. The household dietary diversity score (HDDS) will be calculated following FAO guidelines: http://www.fao.org/3/a-i1983e.pdf
        1. The HDDS for a given dish, calculated as the total count of all food groups represented in the dish (FAO).
        2. The HDDS for a given meal, calculated as:

1. The total count of all food groups represented in the meal.
2. The average of the HDDS over dishes in the meal, such that $E(HDDS_m) = \frac{\sum_{d=1}^{D} HDDS_d}{\sum_{d=1}^{D} dishes}$.

iii. The HDDS for a given day calculated as:
1. The total count of all groups represented in the day.
2. The average of the HDDS over meals in the day.

iv. The HDDS for a given week calculated as:
1. The total count of all groups represented in the week.
2. The average of the HDDS over days in the week.

v. The HDDS for all six weeks calculated as:
1. The total count of all groups represented in the six weeks.
2. The average of the HDDS over days in the six weeks.

- Species richness. The household dietary species richness (SR) will be calculated following Lachat et al. (2018): https://www.pnas.org/content/pnas/115/1/127.full.pdf
  i. The SR for a given dish, calculated as a count of the number of species used as ingredients in the dish.
  ii. The SR for a given meal, calculated as a count of the number of species used as ingredients in the meal.
  iii. The SR for a given day, calculated as a count of the number of species used as ingredients in all meals that day.
  iv. The SR for a given week, calculated as a count of the number of species used as ingredients in all meals that week.
  v. The SR for the six weeks, calculated as a count of the number of species used as ingredients in all meals over the six weeks.
- Number of dishes
  i. Average number of dishes in a meal over the six weeks. (Add up the number of dishes in each meal and divide by the total number of meals the household ate in the six weeks).
  ii. Average number of dishes in breakfast over the six weeks. (Add up the number of dishes in each breakfast and divide by the total number of breakfast meals the household ate in the six weeks).

    iii. Average number of dishes in lunch over the six weeks. (Add up the number of dishes in each lunch and divide by the total number of lunch meals the household ate in the six weeks).
    iv. Average number of dishes in dinner over the six weeks. (Add up the number of dishes in each dinner and divide by the total number of dinner meals the household ate in the six weeks).
- Number of meals skipped
    i. Total number of meals skipped over all six weeks.
    ii. Total number of breakfast meals skipped over all six weeks.
    iii. Total number of lunch meals skipped over all six weeks.
    iv. Total number of dinner meals skipped over all six weeks.

3. Boiling of liquids
    - Milk
        i. The number of times milk was boiled in a given day.
        ii. The number of times milk was boiled in a given week.
        iii. The number of times milk was boiled over all six weeks.
        iv. The volume of milk boiled in a given day.
        v. The volume of milk boiled in a given week.
        vi. The volume of milk boiled over all six weeks.
    - Water
        i. The number of times water was boiled in a given day.
        ii. The number of times water was boiled in a given week.
        iii. The number of times water was boiled over all six weeks.
        iv. The volume of water boiled in a given day.
        v. The volume of water boiled in a given week.
        vi. The volume of water boiled over all six weeks.
    - Liquid (both milk and water)
        i. The number of times liquid was boiled in a given day.
        ii. The number of times liquid was boiled in a given week.
        iii. The number of times liquid was boiled over all six weeks.
        iv. The volume of liquid boiled in a given day.
        v. The volume of liquid boiled in a given week.
        vi. The volume of liquid boiled over all six weeks.
4. Cooking of legumes
    - Count
        i. The number of times legumes were cooked in a given day.
        ii. The number of times legumes were cooked in a given week.
        iii. The number of times legumes were cooked over all six weeks.
    - Volume

i. The volume of legumes cooked in a given day.
ii. The volume of legumes cooked in a given week.
iii. The volume of legumes cooked over all six weeks.

3. Methodology

a. Study area and sampling

The Barotse Floodplain System (BFS), Western Province in Zambia, provides diverse ecosystem services important for local and downstream communities (Schuyt, 2005). The livelihoods and migratory patterns of local communities, the Lozi people, are adapted to the natural flow of the unregulated Upper Zambezi (Tweddle, 2010). The livelihoods of the Lozi depend on fishing, cattle or farming, or a combination of those activities. The floodplain is experiencing severe declines in fish catch rates, fish species, population size and fish diversity (Tweddle, 2010; Tweddle et al., 2015). Shifting cultivation and burning are widely practiced in the area, with large impacts on forest composition, deforestation and regeneration (Wolski, 1998, Tambara, et al., 2012). The communities in Barotse shared their concern about the depletion of their natural resources, particularly regarding fish and forest (Kwashimbisa and Puskur, 2014).

Western Province has one of the highest poverty rates in the country, low agricultural productivity and the region is highly vulnerable to internal and external shocks (Flint 2008; Rajaratnam et al. 2015). Poor sandy soils (Kalahari sands), limited access to agricultural inputs (e.g. manure), equipment, and knowledge about improved management techniques using organic matter (Baidu-Forson et al. 2014) prohibit many rural people from increasing production and productivity. The region experiences a period of four to five months with limited access to food (hunger season) (Castine et al. 2013, Baidu-Forson et al. 2014, Rajaratnam et al. 2015).

The BFS is a pilot Nutrition-Sensitive Landscape (NSL) embedded in CGIAR Research Programs Aquatic Agriculture Systems (ended in January 2016) and Agriculture for Nutrition and Health. Bioversity International lead the characterization of diets, food availability (Pascualino 2014); agrobiodiversity (Baidu-Forson et al. 2014), farming systems (Del Rio 2014) and ecosystem services (Del Rio et al., 2018). Similarly, in collaboration with local partners', three main activities has been promoted and supported to increase knowledge on nutrition, healthy cooking habits, diversify diets and crops named cooking demonstrations-nutrition clubs and learning plots across the eleven villages. During those activities, legumes have been promoted as good and cheap source of proteins while just improving soil fertility and reducing soil erosion as cover crops. However, legumes occupy a minor part of the Lozi diet.

Among the eleven villages in the BFS pilot, we will first randomly select three villages in which to conduct our experiment. Each BFS village has at least two community facilitators (women and men) and one Induna or traditional leader. We will introduce our activities with the community facilitators and Indunas to incorporate their opinions and ideas. They will be in charge of inviting the community to our activities or first events. The invitation for the solar cookers will be open to everyone within the village who is interested.

In each community we will have an introductory day-long event. During the morning we will: 1) start an open discussion with participants about the objectives, commitment and expected results from the solar cookers project; 2) conduct a test and use some of the cookers to make our communal lunch highlighting safety management and precaution measures with a hands-on experience.

During the afternoon session, we will invite those participants interested in the project and in volunteering to have and use the solar stove during six weeks. The commitment is to properly manage the solar stove, record its daily usage for six weeks in the assigned form and record charcoal and firewood consumption during the same period. Households who volunteer to participate will be part of a raffle of the solar stoves at the end of the six week experiment, conditional on their satisfactory completion of their cooking and fuel log. This is to incentivize members of the control group, who do not receive a stove, to record their data through the six weeks.

b. Randomization design

We will stratify our randomization of the stoves based on a household's previous self-selection into one of four groups: 1) cooking demonstrations (nutrition clubs), 2) farmer demonstrations (learning plots), 3) both activities, and 4) no activities. Within each strata and within each village, stoves will be assigned via a random draw (without replacement) of participant names from a bowl.

c. Sample size

Village	AAS activity	Without solar stove	With solar stove	Total
Nalitoya	Learning plots	1		
	Nutritional clubs	28	10	
	Nutritional clubs / Learning plots	11	10	
	None	4		
	Subtotal	*44*	*20*	*64*
Lealui	Learning plots	3	2	
	Nutritional clubs	7	4	
	Nutritional clubs / Learning plots	8	8	
	No data	1	1	
	None	18	5	
	Subtotal	*37*	*20*	*57*
Mapungu	Learning plots	2	1	
	Nutritional clubs	6	2	
	Nutritional clubs / Learning plots	7	11	
	No data	1		
	None	2	5	
	Subtotal	*18*	*19*	*37*
	AAS activities	73	48	
	Non-AAS activities	24	10	
	No data	2	1	
	Total	**99**	**59**	**158**

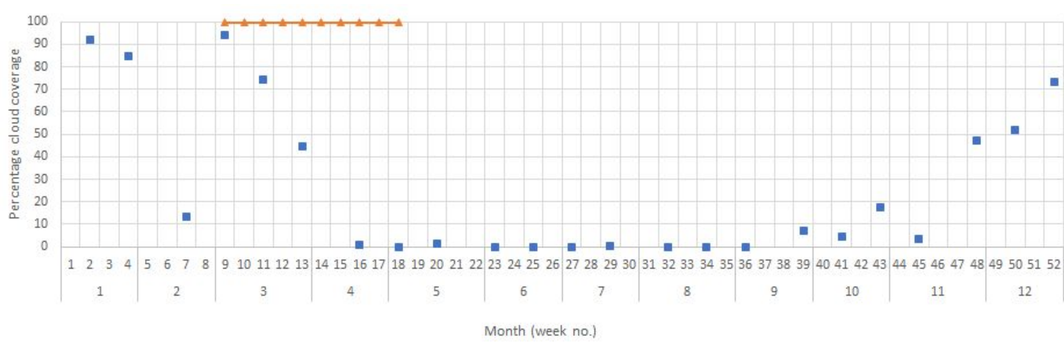
d. Data collection

One nutritionist from NSL-AAS will visit each community and farmer at least four times during the implementation phase, with the goal of reaching every participant, regardless of treatment status, at least twice. The nutritionist will use Kobo toolbox to collect information on each participant (gender, age, school level) and household (size, members, engagement with cooking).

At the start of the experiment, we will provide each household (treatment and control) with a log in which to record the dietary intake, preparation method, and fuel costs. Each household will document the dishes (including all ingredients), and the fuel source used to prepare the dish, for every meal for every day over the six weeks. Households will also record the frequency with which they boil liquids, and the amount of liquid boiled, for each day. They will also record the measured amount of legumes prepared each day, using a standard size measuring cup. Finally, households will record the time and/or money spent each week collecting or purchasing fuel for cooking.

We will have a final meeting to generate feedback from participants and the community. At this final meeting, the logs will be collected as well as all solar stoves. The research team will quickly review the logs and, conditional on satisfactory completeness, each household, regardless of treatment status, will be entered into a random drawing for the solar stoves. As with the initial random assignment, final distribution of the stoves will be via a random draw (without replacement) of participant names from a bowl.

We will also obtain data on cloud cover using Landsat 8 imagery to calculate the percentage of cloud coverage during the period of the experiment. The figure below presents preliminary results for 2016. The orange triangles display the experimental data collecting period.



The Landsat data provides incomplete coverage of our area, in that its flyover of Western Zambia occured only five times during the experiment. For each day in a week that Landsat collected data on cloud cover, we will use the given value of percentage of cloud cover for every day in that week. For days in weeks that Landsat did not collect data, we will use the average value of cloud cover from the preceding and proceeding weeks where there is data.

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Because the Landsat data is incomplete, we may also obtain data on daily rainfall from Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS)

along with rainfall data from European Centre for Medium-Range Weather Forecasts (ECMWF). There can be a great deal of variation in satellite measures of rainfall, especially for CHIRPS in areas where stations are sparse. Because of this uncertainty, we will leave a final decision regarding which source of rainfall data to use until after we have compared data from each source. The determination of source will be based solely on accuracy relative to annual data found at:
https://en.climate-data.org/africa/zambia/western-province/lealui-417551/

The use of satellite rainfall data as a proxy for cloud cover will only be necessary if we find the Landsat cloud cover data to be too infrequently measured to provide predictive power.

4. Estimations

a. Balance checks

We will not collect baseline data for the experiment and therefore will not conduct balance tests between the groups. As Bruhn and McKenzie (2009) write, balance tests raise as many issues as they purport to solve. Given our intensive data collection efforts during the experiment, we have elected to forego a balance.

b. Simple mean differences

We propose to first measure the impact of the interventions by conducting a comparison of means for the intermediate outcomes and final outcomes:

i. Across the treatment and control arms for the entire sample.
ii. Across the treatment and control arms for each group (cooking demonstrations, participation in agricultural demonstrations, or both) in the sample.
iii. Across each group for the treatment.

c. Controls in the regression analysis

We will estimate each of the following econometric models with and without control variables. Our set of control variables includes the following:

- Gender of the household head, measured as 1 if the household head is a woman.
- Age of the household head, measured in number of years.
- Education level of the household head, measured as the highest grade the household help completed.
- Household size, measured as the number of individuals in the household.
- An index of assets owned by the household, measured using the tropical livestock index.

- The percentage of cloud cover, measured using Landsat data (as described above).

d. Estimating intent-to-treat (ITT) effects on intermediate outcomes

While we randomly assigned households to the solar stove treatment, households do not always choose to use their stove to prepare a given dish. Thus, we start by estimating intent-to-treat (ITT) effects on our two intermediate outcomes:

i. Do households with solar stoves use solar stoves?

$$D_{iht} = \alpha + \beta T_h + X_h'\gamma + \mu_v + \varepsilon_{iht}$$

Where $D_{iht} = 1$ if dish i cooked by household h at time t was prepared on a solar stove, and zero otherwise. $T_h = 1$ if the household was randomly assigned a solar stove, X_h is a matrix of controls, μ_v is a dummy for each village v, and ε_{iht} is an idiosyncratic error term clustered at the household-level. We will estimate the equation with and without controls (as listed above). We will also estimate the equation with a linear probability model (LPM) and a probit model.

ii. What percentage of dishes are prepared on solar stoves?

$$S_{ht} = \alpha + \beta T_h + X_h'\gamma + \mu_v + \varepsilon_{ht}$$

Where S_{ht} is the share, as defined above. We will estimate the equation using Ordinary Least Squares (OLS) with and without controls.

e. Estimating intent-to-treat (ITT) effects on final outcomes

Similar to above, because a household's use of the solar stove to prepare a given dish is not random, we estimate ITT effects of being randomly assigned a solar stove on our four final outcomes, measured in various ways:

i. Do households with solar stoves reduce the amount of fuel used to prepare meals?

$$F_{ht} = \alpha + \beta T_h + X_h'\gamma + \mu_v + \varepsilon_{ht}$$

Where F_{ht} is our measure of fuel use, as defined above. We will estimate the equation using OLS with and without controls.

ii. Do households with solar stoves change the composition of their diet?

   1. Dietary diversity

$$HDDS_{iht} = \alpha + \beta T_h + X_h'\gamma + \mu_v + \varepsilon_{iht}$$

Where $HDDS_{iht}$ is our measure of HDDS, as defined above. When the HDDS is measured as a count, following FAO, we will estimate the equation using a Poisson regression with and without controls. When the HDDS is measured as the average, we will estimate the equation using OLS with and without controls.

2. Species richness

$$SR_{iht} = \alpha + \beta T_h + X_h'\gamma + \mu_v + \varepsilon_{iht}$$

Where SR_{iht} is our measure of species richness, as defined above. Given the SR is a count variable, we will estimate the equation using a Poisson regression with and without controls.

3. Number of dishes

$$ND_{ht} = \alpha + \beta T_h + X_h'\gamma + \mu_v + \varepsilon_{ht}$$

Where ND_{ht} is our measure of number of dishes prepared, as defined above. Given the ND is a count variable, we will estimate the equation using a Poisson regression with and without controls.

4. Number of meals skipped

$$MS_{ht} = \alpha + \beta T_h + X_h'\gamma + \mu_v + \varepsilon_{ht}$$

Where MS_{ht} is our measure of meals skipped, as defined above. Given the MS is a count variable, we will estimate the equation using a Poisson regression with and without controls.

iii. Do households with solar stoves boil more liquids?

$$L_{iht} = \alpha + \beta T_h + X_h'\gamma + \mu_v + \varepsilon_{iht}$$

Where L_{iht} is our measure of liquids, as defined above. When liquids are measured as the number of times (count), we will estimate the equation using a Poisson regression with and without controls. When liquids are measured as volume (continuous), we will estimate the equation using OLS with and without controls.

iv. Do households with solar stoves prepare more legumes?

$$P_{iht} = \alpha + \beta T_h + X_h'\gamma + \mu_v + \varepsilon_{iht}$$

Where P_{iht} is our measure of legumes (pulses), as defined above. When legumes are measured as the number of times (count), we will estimate the equation using a Poisson regression with and without controls. When legumes are measured as volume (continuous), we will estimate the equation using OLS with and without controls.

f. Local average treatment effects (LATE)

While we observe which dish is prepared using a solar stove, the use of the stove is not random. We can, however, use the random assignment to the solar stove treatment as an instrument for actual use of the stove. We will re-estimate each of the above specifications using instrumental variables where observed use of the stove is instrumented with random assignment to the solar stove treatment.

g. Heterogeneous effects

We are interested in heterogeneity introduced by a household's self-selection into one of three nutrition/agriculture learning groups. This self selection occured prior to the experiment and we have blocked our randomized based on the pre-experiment self-selection. To identify heterogeneous effects, we estimate the following equation:

$$Y_{iht} = \alpha + \beta_1 T_h + \beta_2 NC_h + \beta_3 LP_h + \beta_4 BA_h + \\ \beta_5 NC_h * T_h + \beta_6 LP_h * T_h + \beta_7 BA_h * T_h + X_h'\gamma + \mu_v + \varepsilon_{iht}$$

Where Y_{iht} is our various intermediate and final outcomes, as discussed above. The various groups are $NC_h = 1$ if an individual in the household is a member of the nutrition club (cooking demonstration), $LP_h = 1$ if an individual in the household is a member of the learning plot group (farmer demonstration), and $BA_h = 1$ if an individual in the household participated in both activities.

h. Spillover effects

We are also interested in the possibility that households randomly assigned to the solar stove treatment change the types of dishes that they cook using traditional methods (wood, charcoal, dung). This would occur if households do not simply substitute the solar stove for existing cooking methods but instead re-optimize their meal planning. To detect if spillovers are present, we will compare the HDDS and SR measures of dietary composition between treatment and control for dishes prepared without the solar stove. If the composition of dishes prepared using traditional sources of fuel by those in the treatment are significantly different from the composition of dishes prepared using traditional sources of fuel by those in the control, this would be a sign of spillovers. To identify spillover effects, we estimate the following equation:

$$DD_{iht} = \alpha + \beta T_h + X_h'\gamma + \mu_v + \varepsilon_{iht}$$

Where DD_{iht} is the dietary diversity, variously measured, of dishes prepared using traditional cooking methods.

i. Hypothesis testing

All standard errors will be clustered at the unit of randomization. Since we consider several outcomes, following Anderson (2008), we plan to implement multiple hypothesis testing within each broad category of outcomes. We will employ sharped q-values, as well as the procedures discussed in List et al. (2016).

5. Addressing incomplete data

We anticipate two potential sources of incomplete data: 1) attrition in keeping the dietary log across the six weeks if the experiment, and 2) failure to record some ingredients/dishes/meals and/or fuel collection and purchases during the six week period.

a. Attrition

We will run a regression of the probability of attrition on treatment status and household observable characteristics measure at baseline. Should we discover differential attrition with respect to the treatment status, we will estimate Lee Bounds (Lee, 2009) as a robustness check on our measures of impact. We will also try to assess the nature of the attrition-induced bias in order to specify whether said bias is upward or downward.

b. Missing data

In asking households to record every ingredient in every meal cooked in every day for six weeks, we expect to have some missing values. In order to minimize this problem, we asked households to explicitly record when meal information is missing because the family did not eat a meal on that day. Thus we can distinguish between skipped meals and missing meals due to a lack of accurate recording.

In order to determine if households that fail to record data are systematically different from households that record data, we will calculate the share of missing meals out of the total number of meals. We will then regress the percentage of missing meals on treatment status and household observable characteristics measure at baseline. Similar to attrition, should we discover differences in data recording we will try to assess the nature of the missing-data-induced bias in order to specify whether said bias is upward or downward.

c. **Dealing with outliers**

To deal with outliers, all continuous variables will be winsorized at the 98th and 2th percentiles at the most disaggregated level possible. Binary and count variables will not be winsorized. Specifications will be checked using both the original and windsorized variables. The stability of coefficients will be tested through standard hypothesis testing (Wald test).

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