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Measuring Macro- and Micronutrient Intake in Multi-Purpose Surveys: Evidence from a Survey Experiment in Tanzania

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Measuring macro- and micronutrient intake in multi-purpose surveys: Evidence from a survey experiment in Tanzania

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Abstract

The nutrition transition in developing countries has increased interest in moving the measurement and analysis of nutritional choice beyond calories to a more complete understanding of macro- and micronutrient consumption. To help move the literature on data collection forward we randomly assigned six different survey modules to measure food consumption across Tanzania, three using diaries and three using recall methods. These modules were chosen to reflect the variety of modules currently in use in multi-purpose household surveys collecting food consumption expenditures in some detail at national scale. They differ by survey observation period, by length of the food recall list, by type of survey reporter (individual reporting or a single reporter per household) and by frequency of interviewer visits. From these data we calculate the percentage consumed relative to daily recommended intakes of calories, protein, fats, sugars, fiber and 16 micronutrients, taking into account age and gender. We also calculate minimum cost diets in each region, using linear programming, and cost-of-basic needs food poverty lines, the prevalence and depth of food poverty according to these lines, and the cost of targeted transfers designed to eliminate food poverty.

Keywords: Consumption, Household surveys, Nutrition, Poverty

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1. Introduction

Nutritious diets are important for human health. Health is not only a prime development outcome, but also feeds into many, if not most, other dimensions of well-being. The development community used to be primarily concerned with hunger, focusing on how many people had insufficient dietary energy and considering what the best ways were to ensure adequate calorie intake. With economic development came a ‘nutrition transition’ adding, alongside hunger, excess calories and nutrient deficiencies to the list of public health concerns in developing countries.¹ The World Health Organisation estimates that one out of three people in the world suffer from either wasting, stunting, vitamin and mineral deficiency, being overweight or obese, or from a diet-related non-communicable disease (WHO, 2017).

At the same time that increased attention has been directed to the nutrition transition, researchers and policy-makers have also gained a deeper appreciation of the physiological connections between nutritional intake and in-utero development, children’s cognitive and physical development and adult health. Consequently, we now have a reasonable idea of what a healthy and environmentally sustainable diet may look like, although it remains unclear how to make it universally available and affordable (Willett et al., 2019; Hirvonen et al., 2019). Policies that aim to improve nutrition require an understanding of how incomes, prices and preferences come together to determine the nutritional choices that consumers make. Understanding such choices lies at the heart of what economics is about and it is therefore no surprise that there is increased interest to move beyond calories towards a ‘new economics of nutrition’ (Finaret and Masters, 2019).

¹ See, for example, Ramakrishnan (2002), Black et al. (2013), Forouzanfar et al. (2013), Pingali and Sunder (2017), Popkin (2017), Perez-Escamilla et al. (2018) and Imamura et al. (2015).

Studying the economics of nutrition is complex as it requires us to understand the consumption of a large number of different macro- and micronutrients that together with individual and environmental circumstances will determine nutritional status. This means moving beyond measuring the effects of nutrient deficiencies (which is what we do when we collect anthropometric data or take haemoglobin test kits to the field) to getting a more complete picture of nutritional intake, broken down into specific food items and their respective macro- and micronutrient contents. Moreover, these detailed nutrition data should, preferably, be part of a survey that collects additional relevant socio-economic information as this information is needed for modelling the determinants of intakes.

Recognising that data collection budgets are finite, one promising avenue would be to assess nutrient intakes through on-going initiatives. A good starting place would be the food consumption modules included in household consumption and expenditure surveys (Zezza et al., 2017), which are conducted at national level across the developing world. They are repeated over time and often include a wide range of other socio-economic information on households and individuals, such as health, education, agriculture and so forth. These modules were not designed to measure nutritional content, being primarily included to measure the monetary value of consumption, from which poverty and inequality indicators can be derived. However, given that food constitutes such a large portion of the consumption expenditures of poor people, such surveys will tend to collect a wealth of food consumption data. For example, food consumption is typically recorded from various sources (whether purchased, home produced or given) and information on quantities consumed of individual food items is often available, which can be linked to its nutritional content. In short, household consumption and expenditures surveys are ubiquitous and hold the potential to reveal something about the nutritional content of what people are eating (De Haen et al., 2011; Fongar et al., 2019).

One concern is that the design of these surveys varies in several dimensions and there is little guidance on the best data collection method (Fiedler et al., 2008; Carletto et al., 2013). This design variation raises concerns about the analytical consequences of using different survey methods and about the potential fragility of results that depend upon comparing across surveys that use different methods (Beegle et al., 2012; Gibson et al., 2014; De Weerd et al., 2016; Friedman et al., 2017). Countries not only differ in methods, but may also change their survey method, which introduces differences over time. For example, recent FAO and World Bank (2018) guidelines for food data collection in household surveys recommend using a 7-day recall, necessitating a switch in survey method for many countries.

To provide evidence on these questions, we randomly assigned six different modules to measure the quantity of food consumption across Tanzania, three using diaries and three using recall methods. The modules differ by survey observation period, by length of the food recall list, by type of survey reporter (individual reporting or a single reporter per household) and by frequency of interviewer visits. Some earlier research using food consumption data from this experiment presents results on the basis of 58 food groups (De Weerd et al., 2016; Friedman et al., 2017). However, these studies only consider the impact of survey design on total calories or on the total value of food consumption.

In contrast to previous studies we provide three innovations. First, we have access to detailed descriptions of the actual foods reported in diaries by the survey respondents. This allows us to disaggregate more finely, using 99 individual food items that we link to Tanzanian food composition tables (Lukmanji et al., 2008). Second, with this link we are able to assign macro- and micronutrient information to all consumed items. From these data we calculate the percentage consumed relative to daily recommended intakes of

calories, protein, fats, sugars, fiber and 16 micronutrients, taking into account the age and gender composition of each household. Our third innovation is to use linear programming to calculate the regional cost of least cost diets that meet all of the macro- and micro-nutrient recommendations. These go beyond the more typically used cost-of-basic-needs food poverty lines. Our motivation for these cost calculations is that survey design not only affects how actual intakes compare to recommendations, but also affects calculated costs of potential public transfers that are designed such that recipients could afford minimally adequate diets.

Our analysis uses the data from the highly supervised individual diaries (based on daily checking on respondents) as our ‘true’ measure of the inflows and outflows of food into the household. When comparing the data from the other five survey modules (household diaries and recall modules) to our ‘true’ food consumption module, the apparent intakes of total and animal-sourced protein, cholesterol and fiber are more sensitive to the use of different consumption modules than is the case for calorie intake. Thus, previous findings that focus solely on calories, such as De Weerd et al (2016), may understate the lack of robustness of nutritional indicators to the variation in survey methods. We also find that using household diaries rather than the highly monitored individual diaries results in the understatement of vitamin and mineral intakes.

Whilst diary modules underestimate macronutrient consumption slightly, 14-day recall modules do so more substantially, underestimating calories by 17%, protein by 40%, fat by 27%, and carbohydrate consumption by 11%. Conversely, the 7-day recall module performs similarly to the household diaries, although overestimating the consumption of carbohydrates, sugar and fiber intake by about 20%. Vitamin and mineral consumption for 7- and 14-day recall modules is also generally underestimated, except for nutrients

derived from higher reported cereal consumption. Important mechanisms that may contribute to the degree of mismeasured nutrient intakes, such as respondent's education, household size, wealth (based on an asset index) and whether they live in urban or rural locations, are also discussed.

When exact macro- and micronutrient intakes cannot be measured, food expenditures can be compared to food poverty lines instead. We construct two such lines. First, the minimum cost (MC) diet, derived through linear programming, is calculated per region to account for price differences across Tanzania. Dar es Salaam is the most expensive region in our sample, with a minimum cost macro- and micronutrient-fulfilling diet of 412 TZS per person, per day (equivalent to US\$ 0.36 per day). The resulting food-poverty prevalence rate varies by survey module. Consistent with the results for understated nutrient intakes, the 14-day recall overestimates the prevalence of extreme food poverty, suggesting that 11% of people in our sample live in households where total food expenditure is below what is needed to buy the minimum cost diet. This is more than twice the rate of extreme food poverty shown with the benchmark individual diary. In contrast, the frequently checked household diary and the 7-day recall perform most closely to the individual diaries at the national level, although with several discrepancies at the regional level.

We then determine how much it would cost to transfer the amount of the shortfall to each household under the food poverty line. Using our benchmarks, the best estimate is USD 51m per year, with the 7-day recall coming quite close with an estimate of USD 69m. The 14-day recall module, by contrast, gives a much more exaggerated annual figure of USD 159m for the same hypothetical programme, working through both an overestimate of the number of people under the MC line and their average shortfall.

Along the same lines, we also calculate a food poverty line based on the typical diet of the poor (specifically, the poorest two quintiles of households) scaled to provide exactly the daily calorie requirement. There is much greater regional variation in this line than the one calculated through linear programming. That is because this food poverty line reflects actual consumer choice, while the linear programming exercise of finding the cheapest combination of foods that satisfy daily recommended intakes does not take any taste considerations into account. We see that the food poverty line is two to three times higher than what comes out of the linear programming calculations in all regions. But, the discrepancy is especially large in Dar es Salaam and Pwani, indicating a stronger preference for more expensive micro- and macronutrients in these places. Together, these two sets of calculations suggest a practical implication of the lack of robustness across the different survey designs; setting possible transfer programs to eliminate food poverty when using some survey designs may produce excessive budgetary requests, which could affect the political feasibility of attempting to eliminate hunger with targeted transfers.

2. Data

The data used in this paper come from a survey experiment where eight types of consumption survey modules were randomly assigned across 4000 households in Tanzania. Data were collected from September 2007 to August 2008. We use data from six modules as the two remaining modules lack the details needed on food quantities to calculate nutrient content. The experiment was fielded in several regions including Dodoma, Pwani, Dar es Salaam, Shinyanga and Kagera, and covers both urban and rural areas. Randomization was conducted within each of the 168 sampling units ('villages'), with each survey module assigned to three households per village. The randomization was successful according to the balance tests reported in Beegle et al (2012).

The survey modules differ by observation period, by length of the food consumption list, by type of survey reporter (individual or a single reporter per household) and by intensity of interviewer visits. Three modules use the recall method, where food consumption is recalled by a single respondent on behalf of the household, in a single verbal interview that covers either the last 7 days or the last 14 days. The recall modules also differ in the number of food and drink groups used to prompt the recall, based on either 58 groups or a subset of 17 important groups.

The other three modules use the diary method, where respondents are to record daily transactions in open form diaries for a 14 day period. They differ in terms of whether reporting is done by each individual adult (who also reports on behalf of children and others for whom they are responsible and who are incapable of completing the diaries) or at the household level where there is a single diary-keeper for the whole household, and in the frequency of interviewer visits. The diary modules are of an acquisition type, adding all products coming into households through harvests, purchases, gifts and stock reductions as well as subtracting all items not consumed, such as through sales, stock increases and gifts. Frequent visits entailed daily visits by the local assistant and visits every other day by the survey enumerator for the duration of the two-week diary. The infrequent visit treatment entails three visits: to deliver the diary (day one), to pick up the first week diary and drop off the week two diary (day eight), and to pick up the second week diary (day 15).

As the diary modules recorded detailed Swahili descriptions of all foods consumed, we exploited this information to disaggregate into 99 food groups. This let us split up important food groups containing multiple types of vegetables or fruit, as well as specific snacks and full meals. In doing so, we were able to link the individually consumed

products or meals to their macro- and micronutrient content using the Tanzanian Food Composition tables (Lukmanji et al., 2008). Using the quantities of food consumed, we calculate calorie intakes, as well as macronutrient consumption of protein, animal protein, fat, saturated fat, cholesterol, carbohydrates, fiber and sugars. Micronutrient consumption was also calculated for vitamins (vitamin A, B1, B2, B3, B6, B9, B12, C and E) and minerals (calcium, phosphorus, iron, sodium, potassium, magnesium and zinc).

In order to facilitate data interpretation, we present calorie² and nutrient consumption relative to the daily recommended intakes. The calorie calculations follow Smith et al., (2006) in determining the daily-required calorie intake per household member taking into account age, sex and breastfeeding. Daily recommended values for macronutrient, vitamin and mineral intakes are derived from Meyers et al (2006), including maximum values to ensure intakes remain under toxicity levels.³ Macro- and micronutrient intake requirements for the average household member are adjusted according to the calculation of their necessary calorie intakes (due to age, sex and breastfeeding status). For example, if the average household member is recommended to consume 2200 kcal per day, then their recommended protein, carbohydrate and fat intakes are scaled upwards from the standard recommendations for a 2000 kcal diet.⁴

² For ease of writing we will continue by including calories when referring to nutrients although they are not technically so. The same will hold for sugar and fiber, subcategories of carbohydrates.

³ The daily recommended intake values of nutrients such as saturated fat, cholesterol and sugars are the maximum values for which they do not negatively impact health.

⁴ For nutrients that are potentially unhealthy when overconsumed, adjustments are only made for calorie intakes below 2000 kcal and maximum levels are maintained for all daily recommended calorie intakes exceeding 2000 kcal. For vitamins and minerals, we ensure they do not exceed toxicity levels.

3. Results

3.1. Diary vs recall modules

We start by reporting average percentage deviations from dietary recommendations, calculated over the ca. 500 households given each of the six survey modules. In the results in Table 1 and 2, positive values represent the percentage by which the requirement is exceeded and negative values are the percentage shortfall from the requirements. For example, for the sample using individual diaries, calorie intakes appear to be 20% above the requirements, while animal protein intakes are 51% below requirements. The results for the sample using individual diaries in column (1) serve as a benchmark to compare with the results from the other survey approaches, given that the individual diary is the most resource intensive survey approach that should come closest to the truth. If the household diaries are used instead of the individual diaries, calories appear to be only 7% (for frequent visits) or 12% (for infrequent visits) above requirements while animal protein appears to be 61% (for frequent visits) or 56% (for infrequent visits) below the recommended dietary allowances.

In column (4) of Table 1, we display a mean across all three types of diaries. It is evident that the main dietary components below requirements are animal protein, fat, cholesterol, Vitamin B9, Vitamin E, Calcium, Sodium and Zinc. Thus, a rise in the consumption of animal products and healthy fats by these households would improve diets.

Table 2 presents similar results to Table 1, but for the samples given recall modules. According to these modules, calories seem almost exactly at the daily recommended values, despite the more accurate individual diaries suggesting that calorie consumption was 20% greater than the requirement. This discrepancy carries through to the apparent individual nutrient intakes. We find similar patterns across nutrients as in Table 1, but

with noticeably different magnitudes. For example, consumption of animal protein seems to be 62 - 69% below requirement compared to 51% below in the benchmark results. It is the 7-day recall that mirrors the personal diary results most closely, although it still overstates the amount by which dietary needs are not being met. The greatest discrepancy from the benchmark results comes from using the 14-day recall module.

Table 1 | Differences in the percentage of nutrient consumption per diary module

	(1)	(2)	(3)	(4)
Percentage consumption relative to RDA	Individual diary, frequent visits, 14 days	Household diary, frequent visits, 14 days	Household diary, infrequent visits, 14 days	Total
Calories	20.28	6.687	11.89	12.96
Macronutrients				
Protein	44.74	25.43	34.83	35.01
Animal protein	-50.55	-61.14	-56.19	-55.96
Fat	-11.03	-24.70	-20.72	-18.81
Saturated fat	63.69	34.42	44.35	47.50
Cholesterol	-74.57	-82.46	-78.18	-78.41
Carbohydrates	50.72	37.39	44.62	44.25
Sugars	33.06	10.13	19.51	20.91
Fiber	66.28	49.33	56.33	57.32
Vitamins				
Vitamin A	34.45	13.13	23.85	23.81
Vitamin B1	25.18	13.56	20.14	19.63
Vitamin B2	164.4	135.8	165.3	155.2
Vitamin B3	40.13	23.54	29.59	31.09
Vitamin B6	75.39	52.99	61.48	63.29
Vitamin B9	2.269	-9.898	-1.867	-3.163
Vitamin B12	72.09	32.03	38.96	47.72
Vitamin C	38.44	17.65	27.71	27.94
Vitamin E	-8.996	1.650	-4.588	-3.981
Minerals				
Calcium	-44.48	-51.74	-47.77	-47.99
Phosphorus	103.8	80.89	91.68	92.12
Iron	34.82	20.58	27.50	27.64
Sodium	-52.83	-58.71	-57.95	-56.49
Potassium	19.36	6.618	12.35	12.78
Magnesium	48.00	35.59	44.20	42.60
Zinc	-1.267	-12.86	-5.389	-6.502

Table 2 | Differences in the percentage of nutrient consumption per recall module, original food groups

Percentage consumption relative to RDA	14 day recall	7 day recall	7 day recall (subset of food groups)	Total
Calories	0.587	0.409	0.415	0.470
Macronutrients				
Protein	6.165	25.26	23.73	18.38
Animal protein	-69.23	-62.86	-67.59	-66.56
Fat	-37.55	-24.92	-29.14	-30.54
Saturated fat	14.47	36.80	51.50	34.26
Cholesterol	-80.70	-77.65	-85.88	-81.41
Carbohydrates	39.70	65.11	84.78	63.20
Sugars	22.98	53.87	34.86	37.24
Fiber	56.94	87.32	91.51	78.59
Vitamins				
Vitamin A	14.36	23.92	81.98	40.08
Vitamin B1	11.85	30.01	47.21	29.69
Vitamin B2	90.61	124.9	191.0	135.5
Vitamin B3	12.05	32.06	26.81	23.64
Vitamin B6	67.10	99.90	113.6	93.54
Vitamin B9	15.65	37.57	44.64	32.62
Vitamin B12	-3.289	4.884	38.79	13.46
Vitamin C	45.13	71.73	89.36	68.74
Vitamin E	14.89	3.265	7.186	8.448
Minerals				
Calcium	-59.08	-50.60	-45.13	-51.60
Phosphorus	63.00	89.98	106.1	86.36
Iron	17.67	37.00	50.07	34.91
Sodium	-67.40	-60.90	-76.51	-68.27
Potassium	29.36	58.62	67.04	51.67
Magnesium	64.48	95.11	104.2	87.93
Zinc	-8.692	7.193	7.400	1.967

In order to empirically test differences in apparent nutrient intakes by module we use a regression analysis. Our ordinary least squares model has the following structure:

$$N_{ik} = \beta_k M_k + e_{ik} \quad (1)$$

where N_{ik} represents the percentage of nutrient consumed relative to the daily recommended intakes, by average household member i assessed using questionnaire k . M_k is a vector of dummy variables for each module type where the personal diaries become our reference category, and e_{ik} is the error term.

Table 3 shows how apparent macronutrient intake relative to daily recommendations varies by module, where the sample given the personal diary module are the reference group. If diaries are conducted at the household level, with one single diary recorder, they show lower levels of macronutrient consumption. This is apparent with both frequent and infrequent enumerator visits. Thus, it appears that relying on a single recorder rather than on individual recording is the design dimension that seems to affect the data.

The understatement of macronutrient consumption is even more apparent when a 14-day recall (again with a single reporter per household) is used. If a 7-day recall is used, with either type of recall list (58 food and drink groups or 17 major items) there is consumption overstatement of carbohydrates, sugar, fiber and (for the subset list) calories, with protein and cholesterol understated. These patterns may reflect a household respondent remembering a higher consumption of starchy foods like maize, rice, bread and cakes than is truly the case. Another reason for overstatement may be that because the recall modules were unbounded, with no initial visit to mark the start of the recall period, telescoping errors could cause respondents to report consumption occurring before the recall period as if it happened during the recall period.

Table 4 shows how apparent intakes of vitamins vary by survey module. For frequently visited household diary and 14-day recall, the discrepancies from the benchmark are often around 20% or larger. These are lower and less prominent for the infrequently visited household diaries. Apparent intakes using 7-day modules are more diverse, with vitamin B2, B3 and B12 understated, but vitamin B6, B9, C and E overstated. If the subset food list is used, all vitamin consumption, bar vitamin B3 and B12, appears to be overstated.

Table 5 presents similar findings for mineral intakes. For the sample given the benchmark diaries, calcium intakes averaged 44% below requirement, as seen from the constant term

in Table 5 (and from Table 1). Yet, intakes would seem even lower, by a further factor of up to 14% points (for 14-day recall) if the other survey modules were used. The pattern of understated intakes holds for most minerals, except potassium and magnesium, and is especially apparent if household diaries or 14-day recall are used. In contrast, the 7-day recall using the full food list provides slight understatements in the consumption of calcium, phosphorus and sodium, but an overstatement in potassium, magnesium and zinc intakes. The 7-day recall using the subset of foods list is more likely to overstate mineral intakes. It must be noted that minerals coming from foods that are difficult to record i.e. sodium from salt, are more likely to be understated across the board.

Table 3 | Effect of module type on apparent macronutrient consumption as a percentage of daily recommended values

VARIABLES	(1) Calories	(2) Protein	(3) Animal protein	(4) Fat	(5) Saturated fat	(6) Cholesterol	(7) Carbohydrates	(8) Sugars	(9) Fiber
Diary: HH, frequent	-13.60*** (5.125)	-19.31*** (4.462)	-10.59*** (2.604)	-13.67 (14.06)	-29.27 (40.51)	-7.890*** (1.652)	-13.33*** (4.675)	-22.93*** (6.427)	-16.95*** (5.621)
Diary: HH, infrequent	-8.389 (5.127)	-9.912** (4.464)	-5.633** (2.605)	-9.689 (14.06)	-19.35 (40.53)	-3.610** (1.653)	-6.102 (4.677)	-13.55** (6.430)	-9.958* (5.624)
Recall: Long, 14 day	-16.93*** (5.120)	-38.58*** (4.457)	-18.68*** (2.601)	-26.52* (14.04)	-49.22 (40.47)	-6.129*** (1.650)	-11.02** (4.670)	-10.07 (6.420)	-9.342* (5.615)
Recall: Long, 7 day	1.835 (5.120)	-19.48*** (4.457)	-12.31*** (2.601)	-13.89 (14.04)	-26.89 (40.47)	-3.072* (1.650)	14.39*** (4.670)	20.81*** (6.420)	21.04*** (5.615)
Recall: Subset, 7 day	11.70** (5.120)	-21.02*** (4.457)	-17.04*** (2.601)	-18.11 (14.04)	-12.19 (40.47)	-11.31*** (1.650)	34.06*** (4.670)	1.801 (6.420)	25.22*** (5.615)
Constant	20.28*** (3.622)	44.74*** (3.153)	-50.55*** (1.840)	-11.03 (9.934)	63.69** (28.63)	-74.57*** (1.167)	50.72*** (3.304)	33.06*** (4.542)	66.28*** (3.973)
R-squared	0.014	0.027	0.024	0.001	0.001	0.019	0.048	0.018	0.031

Note: Each column presents estimates of equation (1), where the left hand side variable is the deviation from the daily recommended intake of the nutrient indicated in the column heading. Standard errors are in parentheses under the coefficient. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. $N = 3,018$.

Table 4 | Effect of module type on apparent vitamin consumption as a percentage of daily recommended values

VARIABLES	(1) Vitamin A	(2) Vitamin B1	(3) Vitamin B2	(4) Vitamin B3	(5) Vitamin B6	(6) Vitamin B9	(7) Vitamin B12	(8) Vitamin C	(9) Vitamin E
Diary: HH, frequent	-21.32* (11.24)	-11.63*** (3.940)	-28.58** (12.04)	-16.59*** (4.416)	-22.40*** (6.581)	-12.17** (4.922)	-40.06*** (14.14)	-20.79** (8.490)	10.65 (6.984)
Diary: HH, infrequent	-10.60 (11.25)	-5.041 (3.942)	0.922 (12.05)	-10.54** (4.418)	-13.90** (6.585)	-4.136 (4.925)	-33.13** (14.15)	-10.73 (8.494)	4.408 (6.988)
Recall: Long, 14 day	-20.09* (11.23)	-13.33*** (3.937)	-73.80*** (12.03)	-28.07*** (4.411)	-8.287 (6.575)	13.39*** (4.918)	-75.38*** (14.13)	6.689 (8.482)	23.89*** (6.977)
Recall: Long, 7 day	-10.53 (11.23)	4.827 (3.937)	-39.54*** (12.03)	-8.062* (4.411)	24.52*** (6.575)	35.30*** (4.918)	-67.21*** (14.13)	33.29*** (8.482)	12.26* (6.977)
Recall: Subset, 7 day	47.53*** (11.23)	22.03*** (3.937)	26.57** (12.03)	-13.32*** (4.411)	38.25*** (6.575)	42.37*** (4.918)	-33.30** (14.13)	50.92*** (8.482)	16.18** (6.977)
Constant	34.45*** (7.944)	25.18*** (2.785)	164.4*** (8.513)	40.13*** (3.121)	75.39*** (4.651)	2.269 (3.479)	72.09*** (9.995)	38.44*** (6.000)	-8.996* (4.936)
R-squared	0.017	0.035	0.028	0.015	0.041	0.063	0.012	0.033	0.005

Note: Each column presents estimates of equation (1), where the left hand side variable is the deviation from the daily recommended intake of the nutrient indicated in the column heading. Standard errors are in parentheses under the coefficient. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. $N=3,018$.

Table 5 Effect of module type on apparent mineral consumption as a percentage of daily recommended values

VARIABLES	(1) Calcium	(2) Phosphorus	(3) Iron	(4) Sodium	(5) Potassium	(6) Magnesium	(7) Zinc
Diary: HH, frequent	-7.259*** (2.317)	-22.87*** (6.044)	-14.24*** (4.269)	-5.874** (2.389)	-12.74** (6.032)	-12.41** (5.379)	-11.59*** (3.258)
Diary: HH, infrequent	-3.294 (2.318)	-12.08** (6.047)	-7.322* (4.271)	-5.118** (2.390)	-7.007 (6.035)	-3.808 (5.382)	-4.122 (3.260)
Recall: Long, 14 day	-14.60*** (2.315)	-40.76*** (6.038)	-17.15*** (4.265)	-14.56*** (2.387)	10.00* (6.026)	16.48*** (5.374)	-7.424** (3.255)
Recall: Long, 7 day	-6.125*** (2.315)	-13.78** (6.038)	2.183 (4.265)	-8.067*** (2.387)	39.26*** (6.026)	47.11*** (5.374)	8.460*** (3.255)
Recall: Subset, 7 day	-0.654 (2.315)	2.342 (6.038)	15.24*** (4.265)	-23.68*** (2.387)	47.68*** (6.026)	56.20*** (5.374)	8.667*** (3.255)
Constant	-44.48*** (1.638)	103.8*** (4.272)	34.82*** (3.017)	-52.83*** (1.688)	19.36*** (4.263)	48.00*** (3.802)	-1.267 (2.303)
R-squared	0.016	0.022	0.024	0.039	0.055	0.086	0.021

Note: Each column presents estimates of equation (1), where the left hand side variable is the deviation from the daily recommended intake of the nutrient indicated in the column heading. Standard errors are in parentheses under the coefficient. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. $N=3,018$.

3.2. Heterogeneity analysis

Various household characteristics may affect module performance. For example, a more educated respondent may provide more accurate reports of food consumed over the past period and this may matter more as the period lengthens compared to a daily diary entry (especially as interviewers and survey assistants checked daily). On the other hand, households in urban areas or with more wealth likely consume a greater variety of food, adding to the complexity of the reporting task, especially for recall modules. Lastly, household size and how many young children are present in the household could affect the focus of the respondent and the time spent on diary recording. In other words, the potential accuracy of some of the designs depends more heavily on respondent characteristics than is the case for other designs. Therefore, we run similar regressions to those in section 3.1., but now including several selected household characteristics and an interaction term between the household characteristic and module type, as follows:

$$N_{ik} = \beta_k M_k + \beta_x X_{ik} + \delta_k M_k X_{ik} + e_{ik} \quad (2)$$

where X_{ik} is a single household characteristic and δ_k represents the coefficient for the interaction term. This equation is estimated individually, per household characteristic. The household characteristics we use are household size, education of the household head, household wealth, the share of children under 6 and whether the household lives in an urban area.

Table 6 presents a summary of the results of the heterogeneity analysis (full regression tables can be found in Table A1-A5 in the Appendix). Panel A of this table shows which modules have positive (non-bold) or negative (bold) interaction effects for the household characteristic indicated in the column when assessing the consumption of the nutrient

indicated in the row. Panel B of Table 6 summarises these results by simply counting per characteristic and per module how many significant (at the 5% level) interaction effects there are. When interpreting Panel B it is useful to keep in mind that Panel A assesses the modules for 25 nutrients across 5 household characteristics and so is assessed 125 times. From Panel B we can see that the characteristics that appear to matter most to the relative performance of survey modules are household size and urban location, with 32 and 36 significant interaction effects. Household wealth, education of the household head and the share of children under 6 have far fewer significant interaction effects (16, 13 and 11, respectively, out of a possible total of 125).

For household size, it appears that respondents in larger households report relatively less when using recall modules (of either 7 or 14 day duration). The effect holds for all minerals, for all vitamins except Vitamin B2, B12 and E, and for calories and protein. In other words, the gap between the intakes measured when using benchmark individual diaries and what is measured using recall methods is bigger for larger households. This pattern is consistent with prior evidence of recall surveys increasingly understating food consumption as household size grows, because larger households have more people to report on and so in a given time interval will have more food transactions to recall (Gibson and Kim, 2007). In contrast, almost no nutrient intake is differentially affected by household size when various types of diaries are used.

Whether the household is in a rural or urban area also seems to matter. Recall modules often seem to mistakenly understate the macro- and micronutrient consumption of urban households compared to what the benchmark shows. Recall likely misses more complex urban consumption patterns that are less reliant on common-pot eating; thus, a recall respondent in an urban area may be less informed about the food consumption of the other

household members than is the case in a rural area. As can be seen from column (3) this is not a pure wealth effect, as wealth has half the number of significant interaction effects.

Finally, the share of children under 6 years of age and the years of formal education of the household head have the lowest count of significant interaction effects and the effects are concentrated overwhelmingly in the recall modules.

Table 6 | Significant interactions between module type and selected household characteristics

PANEL A – Significant effects

	Household characteristics				
	(1)	(2)	(3)	(4)	(5)
Percentage consumption relative to RDA	Household size	Education household head	Wealth	Share children under 6	Urban household
Calories	4	-	5	-	3, 4
Protein	4	1	3, 4	4	-
Animal protein	-	-	1, 3, 4, 5	4	1, 3, 4, 5
Fat	5	-	5	-	-
Saturated fat	5	-	5	-	-
Cholesterol	-	1, 5	1, 2	-	1, 2
Carbohydrates	3, 4, 5	4, 5	5	-	3, 4, 5
Sugars	1, 4, 5	-	5	-	-
Fiber	3, 4, 5	4, 5	5	-	3, 5
Vitamin A	5	-	-	-	5
Vitamin B1	3, 4, 5	4, 5	5	-	3, 4, 5
Vitamin B2	-	-	2	-	-
Vitamin B3	4	-	-	-	3, 5
Vitamin B6	3, 4, 5	-	-	4, 5	3, 4, 5
Vitamin B9	3, 4, 5	-	-	4, 5	5
Vitamin B12	-	-	1	-	1, 2
Vitamin C	4	-	5	4, 5	5
Vitamin E	4	-	-	-	5
Calcium	3, 4, 5	-	3, 4, 5	3, 4, 5	3, 4
Phosphorus	3, 4, 5	-	-	4	5
Iron	3, 4, 5	-	-	-	3, 4, 5
Sodium	4	3, 4	3, 4	3, 4	3, 4
Potassium	3, 4, 5	-	5	5	3, 4, 5
Magnesium	4, 5	3, 4, 5	3, 4, 5	-	3, 4, 5
Zinc	4	3	-	4	-

PANEL B – Count of significant effects in PANEL A

	(1)	(2)	(3)	(4)	(5)	(6)
	Household size	Education household head	Wealth	Share children under 6	Urban household	TOTAL
1. Diary: HH, frequent	1	1	2	0	3	7
2. Diary: HH, infrequent	0	0	1	0	2	3
3. Recall: Long, 14 day	9	2	5	2	12	30
4. Recall: Long, 7 day	11	5	5	5	10	36
5. Recall: Subset, 7 day	11	5	3	4	9	32
TOTAL	32	13	16	11	36	108

Note: Panel A shows the results of estimating equation (2) separately for each combination nutrient indicated in the row and the household characteristic indicated in the column. The cells indicate for which module the interaction effects are significant at the 5% level, with a bold number representing a negative coefficient and a non-bold number a positive one. The modules are represented with the following numbers 1 (Diary HH, frequent), 2 (Diary HH, infrequent), 3 (Recall 14 days), 4 (Recall 7 days), 5 (Recall 7 days subset). A dash (-) means there are no positive effects for any module for that combination of nutrient and household characteristic. Panel B then counts the number of significant effects in Panel A (positive or negative) per module and per household characteristic.

Looking at the last column in Panel B, which summarises the total number of significant interaction effects across all 5 modules, we see that the household diaries have much lower counts than the recall modules. All recall modules have many significant interaction effects. Especially the 7-day recall stands out, with almost 36 significant effects out of a total of 125 possible effects. These patterns confirm that the potential accuracy of some module designs, particularly recall modules, are more subject to variation according to respondent characteristics than is the case for other designs.

3.3. Food poverty

Where analysts lack data on food quantities consumed or surveys do not have the required granularity in food items to accurately determine macro- and micronutrient intakes, there may be interest in comparing the value of total food consumption expenditures against a minimum threshold. These comparisons may also be motivated by the insight that interventions to improve nutrition ultimately have to be budgeted for, and so monetary-based calculations can be useful because they are in the same metric (dollars or TZ

shillings in this case) that is used when nutritional intervention programs are funded. We conduct such an exercise with two thresholds.

In the first we use linear programming to determine, per region, the minimal cost of a diet that meets all nutrient requirements (Allen, 2017). We call the diet in question the MC diet and the corresponding cost the MC diet poverty line. We then compute the share of households whose food expenditures lie below the MC diet poverty line. This provides a minimum bound on the calculation of nutrient deprived households: we can be sure that these households are facing nutrient deficiencies, although we cannot be sure that those whose value of food consumed is above the threshold are eating healthy diets. For those with a food consumption shortfall, we also calculate the average gap between the value of the household's food consumption and the price of the MC diet in their region.

The second threshold scales, per region, the cost of the typical diet of the 40% poorest to ensure it provides sufficient calories for the household. We call this the food poverty line (as the scaled basket is one component of cost-of-basic-needs poverty lines). We also calculate the share of households whose food expenditures lie below it and, conditional on that, the average gap.

Both poverty lines are calculated using the highly supervised individual diaries, which we believe contain the most accurate information on prices and expenditures. For the MC diet, prices are median region-level unit prices for each of the 99 food items recorded in the diaries. Ideally, we would have used a price survey for this exercise, but the one conducted as part of this survey experiment was not done with sufficient granularity to confidently calculate the least cost diet.

Table 7 shows the two poverty lines, broken down by region. A number of interesting facts emerge. First, the food poverty line is much higher than the MC diet poverty line in

all regions. The diets of the poorest 40% are 2-3 times more expensive than what would be strictly needed to meet all nutrient requirements. Second, there is much more regional variation in the food poverty line than in the MC diet poverty line. Especially Dar es Salaam has a higher poverty line than other regions, which is less evident from Dar es Salaam's MC diet poverty line. Therefore, the higher food poverty line is not just due to higher prices in Dar es Salaam, but also reflects the choice of consumers there for more expensive sources of macro- and micronutrients.

A final interesting example is Pwani, which has the cheapest MC diet at TZS 228 per person per day, yet the food poverty line in Pwani is the highest after Dar es Salaam in our sample, at TZS 746 per person per day. Thus, it appears that consumers in Pwani are choosing relatively higher-priced micro- and macronutrients, perhaps due to a culture of eating outside the household in this specific case.

Table 7 | Minimum cost diet and cost of basic needs food poverty lines per region

	Minimum cost diet food poverty line (TZS)	Cost of basic needs food poverty line (TZS)
Dodoma	320.17	710.40
Pwani	227.84	746.08
Dar es Salaam	411.76	1444.25
Shinyanga	310.42	617.94
Kagera	257.75	695.46

Let us now bring our experimental variation back in to look at how the different survey methods would assess the prevalence and depth of food poverty compared to these lines. We do so by comparing total household food expenditures, as measured by each of the modules, to the region-specific poverty lines listed in Table 7. Table 8 does this for the set of MC diet poverty lines, with panel A showing the percentage of households whose

food expenditures fall below the threshold and panel B the percentage of the shortfall per person per day, i.e. the average gap for the food-poor.⁵

Table 8 portrays a situation that is consistent with the results for understated nutrient intakes. The 14-day recall overestimates the prevalence of extreme food poverty, suggesting that 11% of people in Tanzania live in households where total food expenditure is below what is needed to buy the MC diet. This is more than twice the rate of extreme food poverty shown with the benchmark individual diary. Likewise, with the 14-day recall, the poverty gap of the food poor is overstated by about one third. In contrast, the infrequent household diary and 7-day recall modules perform most closely to the individual diaries at the national level, although with several discrepancies at the regional level.

Another instructive exercise is to sum all food consumption shortfalls in our sample. A hypothetical perfectly targeted transfer program of this size could give all households the freedom to eat a healthy diet without compromising on current non-food expenditures. Of course there is no guarantee that households would spend this amount on nutritious food, nor that the transfer would not spillover into increasing non-food expenditures, but it is a useful benchmark to keep in mind how much households are short when it comes to purchasing a healthy diet. According to the personal diaries, our hypothetical transfer programme would need to provide each MC diet food poor household 60 TZS per person per day to lift it up to the MC diet line. Extrapolating the 4.73% of the total sample under this line to the 57m people in the whole of Tanzania implies a cost of just under TZS 162m in total per day or about USD 51m a year.⁶ However, if we were to budget based

⁵ Table A6 contains similar results for the food poverty line. The findings are similar to those in Table 8, but with higher rates of households with expenditures below the threshold and with larger shortfalls.

⁶ The average exchange rate during the study period was TZS 1,150 for one USD.

on the guidance provided by a 14-day recall survey, the estimated cost would be over \$100 million higher, at USD 159m per year, which is a significant bias in the forecast costs. Carrying on with these calculations, the 7-day recall gives a much more reasonable estimate, putting the cost of perfectly targeted transfers at USD 69m.⁷

Table 8 | Extreme food poverty

A: Households spending below minimum cost diet threshold (%)						
	Dodoma	Pwani	Dar es Salaam	Shinyanga	Kagera	Total
Diary: Personal	5.65	9.64	0.00	6.77	1.25	4.73
Diary: HH, frequent	7.37	1.61	1.69	14.47	4.55	7.61
Diary: HH, infrequent	6.85	2.31	3.83	11.28	2.09	6.19
Recall: Long, 14 day	4.79	3.10	0.00	22.70	6.90	11.35
Recall: Long, 7 day	1.96	3.35	0.00	16.39	4.89	7.77
Recall: Subset, 7 day	8.65	0.00	0.93	22.09	2.26	9.54
B: Average poverty gap of the food-poor (%)						
	Dodoma	Pwani	Dar es Salaam	Shinyanga	Kagera	Total
Diary: Personal	17.43	14.20	0.00	24.70	5.38	19.63
Diary: HH, frequent	29.17	41.59	17.65	19.69	17.06	20.91
Diary: HH, infrequent	24.41	4.51	5.74	17.32	25.67	17.50
Recall: Long, 14 day	17.76	11.60	0.00	27.29	22.23	25.39
Recall: Long, 7 day	2.76	2.30	0.00	19.11	9.96	16.04
Recall: Subset, 7 day	8.20	0.00	14.25	13.86	31.36	14.32

4. Conclusion

Using a unique survey experiment, we have been able to assess survey performance in recording macro- and micronutrient consumption, as well as food poverty rates, across 3000 households in Tanzania. Our analyses are motivated by two factors: the growing attention to the nutrition transition means that the focus of many interventions is moving beyond calories; and, some of the most available sources of information are multi-topic household surveys. Yet, even while the confluence of these two factors may see more nutritional analyses based on data from multi-topic household surveys, a threat to the validity of these analyses is that the food consumption modules of these surveys differ in

⁷ These values are much higher if calculated based on the food poverty line and food poverty shortfall from Table A6, at USD 2.119 billion for personal diaries, USD 3.418 billion for the 14-day recall and USD 2.293 billion for the full food list 7-day recall.

several key dimensions. While these issues have been studied before, especially in the collection of articles introduced by Zezza et al (2017) there remains much that is unknown, especially when the focus moves beyond calories.

One of the key results to emerge from the current experiment is that the 14-day recall modules led to the largest understatements of both macro- and micronutrient intakes. The 7-day recall module is found to perform closest to the personalized diaries, although particular attention to cereal and other carbohydrate consumption must be considered when using this module design. Household diaries also prove to be less accurate than highly supervised individual diaries, with it being the reliance on a single reporter rather than individual-based reporting that seems to matter. Comparing survey modules in terms of their performance at the nutrient level as well as at the calorie level has also proven important, with greater sensitivity of apparent protein and cholesterol consumption than is shown for calorie intake. Apparent vitamin and mineral intakes also vary substantially with choice of survey module, which has important implications for surveys that aim to take dietary quality measures into account. Previous findings that focus solely on calories may understate the lack of robustness of nutritional indicators to the variation in survey methods.

Furthermore, we found that recall modules are more sensitive to household characteristics than diary modules are. For example, larger household size and urban location are cause for recall modules to further underestimate actual consumption levels. It seems that having more members to recall for and a more diverse availability of foods and less reliance on common-pot eating in urban areas can make recall modules more difficult for respondents than they are in rural settings. Education levels of the household head and wealth had slightly less effect on the results. While the factors that underlie these patterns

may occur more universally, we caution that the performance of diaries in this experiment, in terms of results being less affected by respondent characteristics and also not just providing benchmark results in the resource intensive variant but also results that are fairly close to the benchmark for other variants, may not translate into other settings. We had great cooperation from respondents and interviewers were skilled and experienced, and more intensively trained and supervised than typical for developing country surveys. Thus, common diagnostics of problems with diary surveys, such as incomplete diaries or fatigue as the diary-keeping period progresses, are not apparent in this experiment (Beegle et al, 2012). In contrast, in other experiments, and under more usual field conditions with statistics offices, diary surveys often have many partially completed or uncompleted records and compliance is likely to vary with household characteristics (Sharp et al, 2019).

Lastly, the disparities in nutrient intake between survey modules are also observed for food poverty lines, where all module designs except for the 7-day recall overestimate food poverty in Tanzania. Consequently, the calculation of possible transfer programs to eliminate food poverty would produce excessive budgetary requests if the evidence base was built with surveys such as these. These excessive budgetary requests could affect the political feasibility of attempting to eliminate hunger with targeted transfers.

Although each survey design comes with potential benefits and shortcomings, the results here could be taken as support for the FAO/WB recommendations for food consumption surveys to use 7-day recall, rather than longer period recall or diaries (Zezza et al., 2017). In particular, we find that 7-day recalls are relatively good at predicting average nutrient intakes, and also provide good predictions for the prevalence and depth of food poverty. Thus, such surveys could be a reasonable basis for estimating the needed scale of transfer programmes designed to alleviate food poverty. Nevertheless, we caution that even

though the nutrient consumption values recorded through the 7-day recall are more likely than other modules to be correct on average, this design is rather sensitive to household characteristics. One reason for this, explored in some detail in Friedman et al. (2017), is that the 7-day recall has offsetting errors that seem to roughly balance: there are incidence errors within several important food groups (that is, entirely forgetting to report any consumption) that are offset by the overstatement of the value of what was consumed conditional on reporting any consumption. One explanation for this pattern is telescoping errors, where consumption that occurred before the recall period is reported as if it was in the recall period, where these errors will have a larger impact on a 7-day recall than a 14-day recall (as they are amortized over fewer days). Hence, a recommendation for any future experiments on this topic is to include treatments that can inform about telescoping, such as the use of an initial visit to bound the recall period.

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APPENDIX

Table A1 | Interaction terms between module type and household size

VARIABLES	(1) Calories	(2) Protein	(3) Animal protein	(4) Fat	(5) Saturated fat	(6) Cholesterol	(7) Carbohydrates	(8) Sugars	(9) Fibre
Diary: HH frequent * household size	0.792 (1.734)	0.335 (1.500)	0.612 (0.882)	2.948 (4.797)	8.506 (13.84)	0.589 (0.560)	0.754 (1.567)	4.209** (2.117)	0.176 (1.892)
Diary: HH infrequent * household size	0.943 (1.715)	2.119 (1.483)	1.518* (0.872)	2.806 (4.744)	6.382 (13.68)	0.617 (0.553)	0.436 (1.549)	1.699 (2.093)	0.550 (1.870)
Recall: Long, 14 day * household size	-3.084* (1.742)	-2.706* (1.507)	-0.236 (0.886)	1.064 (4.819)	3.231 (13.90)	-0.653 (0.562)	-5.216*** (1.574)	-3.732* (2.127)	-6.676*** (1.900)
Recall: Long, 7 day * household size	-4.864*** (1.814)	-3.718*** (1.569)	-0.545 (0.923)	1.082 (5.018)	2.651 (14.47)	-0.166 (0.585)	-8.279*** (1.639)	-8.053*** (2.214)	-8.904*** (1.978)
Recall: Subset, 7 day * household size	-0.295 (1.811)	-1.990 (1.566)	-0.276 (0.921)	12.48** (5.008)	34.66** (14.45)	0.322 (0.584)	-6.686*** (1.636)	-5.847*** (2.210)	-6.414*** (1.975)
VARIABLES	(10) Vitamin A	(11) Vitamin B1	(12) Vitamin B2	(13) Vitamin B3	(14) Vitamin B6	(15) Vitamin B9	(16) Vitamin B12	(17) Vitamin C	(18) Vitamin E
Diary: HH frequent * household size	3.076 (3.802)	0.125 (1.331)	-3.880 (4.094)	0.659 (1.482)	1.669 (2.198)	0.301 (1.630)	2.242 (4.808)	2.193 (2.883)	-1.007 (2.374)
Diary: HH infrequent * household size	1.552 (3.760)	0.266 (1.317)	-3.570 (4.048)	2.232 (1.465)	1.499 (2.173)	1.306 (1.612)	6.264 (4.754)	0.0980 (2.851)	-1.063 (2.347)
Recall: Long, 14 day * household size	-0.457 (3.820)	-3.996*** (1.337)	-5.309 (4.112)	-2.517* (1.489)	-4.919** (2.208)	-5.541*** (1.637)	1.692 (4.830)	-4.709 (2.896)	0.131 (2.384)
Recall: Long, 7 day * household size	-7.560* (3.977)	-5.290*** (1.393)	-6.599 (4.282)	-3.735** (1.550)	-10.11*** (2.299)	-8.482** (1.705)	0.745 (5.029)	-9.629*** (3.016)	4.956** (2.483)
Recall: Subset, 7 day * household size	-8.847** (3.970)	-4.716*** (1.390)	-7.895* (4.273)	-2.614* (1.547)	-6.610*** (2.294)	-4.772*** (1.702)	0.210 (5.019)	-5.709* (3.010)	1.481 (2.478)
VARIABLES	(19) Calcium	(20) Phosphorous	(21) Iron	(22) Sodium	(23) Potassium	(24) Magnesium	(25) Zinc		
Diary: HH frequent * household size	-0.754 (0.787)	-0.311 (2.044)	-0.302 (1.440)	0.329 (0.795)	1.287 (2.014)	0.788 (1.794)	0.796 (1.085)		
Diary: HH infrequent * household size	0.105 (0.778)	2.015 (2.021)	0.877 (1.423)	1.061 (0.786)	1.019 (1.991)	2.229 (1.774)	1.995* (1.072)		
Recall: Long, 14 day * household size	-2.345*** (0.790)	-5.553*** (2.053)	-4.558*** (1.446)	-1.383* (0.799)	-4.814** (2.023)	-3.555** (1.802)	-1.967* (1.089)		
Recall: Long, 7 day * household size	-3.035*** (0.823)	-6.871*** (2.138)	-5.258*** (1.506)	-3.039*** (0.832)	-9.591*** (2.106)	-5.769*** (1.877)	-2.963*** (1.134)		
Recall: Subset, 7 day * household size	-2.483*** (0.821)	-5.059** (2.134)	-3.957*** (1.503)	0.805 (0.830)	-7.574*** (2.103)	-4.683** (1.873)	-1.252 (1.132)		

Table A2 | Interaction terms between module type and years of education (hhh)

VARIABLES	(1) Calories	(2) Protein	(3) Animal protein	(4) Fat	(5) Saturated fat	(6) Cholesterol	(7) Carbohydrates	(8) Sugars	(9) Fibre
Diary: HH frequent * education (hhh)	-1.315 (1.359)	-2.355** (1.180)	-1.208* (0.678)	-1.666 (3.719)	-3.899 (10.72)	-1.140*** (0.420)	-1.027 (1.235)	2.156 (1.686)	-1.651 (1.470)
Diary: HH infrequent * education (hhh)	-0.173 (1.348)	-1.396 (1.171)	-0.648 (0.672)	-0.220 (3.690)	0.996 (10.64)	-0.642 (0.417)	-0.294 (1.225)	0.780 (1.672)	-1.716 (1.458)
Recall: Long, 14 day * education (hhh)	-1.518 (1.342)	-0.486 (1.166)	0.570 (0.669)	-2.396 (3.673)	-5.371 (10.59)	-0.0633 (0.415)	-1.635 (1.220)	-0.348 (1.665)	-2.021 (1.452)
Recall: Long, 7 day * education (hhh)	-1.810 (1.354)	0.333 (1.176)	1.088 (0.675)	-0.933 (3.705)	-2.277 (10.68)	-0.0296 (0.419)	-3.150** (1.231)	-0.171 (1.679)	-3.363** (1.464)
Recall: Subset, 7 day * education (hhh)	-0.518 (1.343)	-0.288 (1.167)	0.539 (0.670)	1.815 (3.677)	6.076 (10.60)	-0.987** (0.415)	-3.061** (1.221)	2.709 (1.667)	-3.191** (1.453)
VARIABLES	(10) Vitamin A	(11) Vitamin B1	(12) Vitamin B2	(13) Vitamin B3	(14) Vitamin B6	(15) Vitamin B9	(16) Vitamin B12	(17) Vitamin C	(18) Vitamin E
Diary: HH frequent * education (hhh)	-1.965 (2.956)	-1.418 (1.033)	-0.517 (3.173)	-1.418 (1.172)	-0.00764 (1.743)	-0.0849 (1.306)	-5.131 (3.635)	0.581 (2.245)	0.0661 (1.854)
Diary: HH infrequent * education (hhh)	-1.931 (2.933)	-1.092 (1.025)	-5.072 (3.148)	-0.806 (1.162)	-1.075 (1.729)	-0.623 (1.296)	-2.309 (3.606)	-1.282 (2.227)	0.623 (1.839)
Recall: Long, 14 day * education (hhh)	-0.588 (2.919)	-1.408 (1.021)	2.066 (3.133)	-0.838 (1.157)	0.404 (1.722)	-0.0223 (1.290)	-5.791 (3.590)	2.426 (2.217)	-0.912 (1.831)
Recall: Long, 7 day * education (hhh)	-0.889 (2.945)	-2.212** (1.030)	-1.773 (3.161)	-0.739 (1.167)	-2.162 (1.737)	-1.085 (1.301)	-4.159 (3.622)	-2.869 (2.237)	-0.513 (1.847)
Recall: Subset, 7 day * education (hhh)	1.782 (2.923)	-2.501** (1.022)	-2.282 (3.137)	-1.277 (1.158)	-1.828 (1.723)	-0.850 (1.291)	-1.843 (3.594)	-0.795 (2.220)	-0.272 (1.833)
VARIABLES	(19) Calcium	(20) Phosphorous	(21) Iron	(22) Sodium	(23) Potassium	(24) Magnesium	(25) Zinc		
Diary: HH frequent * education (hhh)	-0.284 (0.611)	-2.692* (1.600)	-1.650 (1.126)	0.202 (0.625)	0.317 (1.596)	-0.765 (1.417)	-1.002 (0.861)		
Diary: HH infrequent * education (hhh)	-0.688 (0.606)	-1.923 (1.588)	-1.337 (1.117)	0.249 (0.620)	-0.391 (1.584)	-0.257 (1.406)	-0.535 (0.854)		
Recall: Long, 14 day * education (hhh)	0.758 (0.603)	-1.932 (1.581)	-1.189 (1.112)	1.404** (0.617)	0.387 (1.577)	-3.832*** (1.400)	-2.345*** (0.850)		
Recall: Long, 7 day * education (hhh)	0.776 (0.609)	-1.166 (1.595)	-1.348 (1.122)	1.371** (0.623)	-2.524 (1.591)	-4.382*** (1.412)	-1.554* (0.858)		
Recall: Subset, 7 day * education (hhh)	0.370 (0.604)	-1.687 (1.582)	-1.747 (1.113)	-0.468 (0.618)	-2.124 (1.578)	-4.334*** (1.401)	-1.093 (0.851)		

Table A3 | Interaction terms between module type and wealth

VARIABLES	(1) Calories	(2) Protein	(3) Animal protein	(4) Fat	(5) Saturated fat	(6) Cholesterol	(7) Carbohydrates	(8) Sugars	(9) Fibre
Diary: HH frequent * asset index	-3.351 (5.122)	-7.234 (4.398)	-5.579** (2.540)	-9.343 (14.02)	-24.42 (40.44)	-4.864*** (1.564)	-1.279 (4.666)	7.442 (6.340)	-3.422 (5.581)
Diary: HH infrequent * asset index	-2.723 (5.129)	-4.485 (4.403)	-2.273 (2.543)	-9.039 (14.04)	-18.33 (40.50)	-3.409** (1.566)	-1.861 (4.673)	3.792 (6.348)	-3.996 (5.588)
Recall: Long, 14 day * asset index	-5.198 (5.038)	9.970** (4.325)	7.395*** (2.498)	-8.665 (13.79)	-27.02 (39.78)	1.522 (1.538)	-5.822 (4.589)	2.448 (6.235)	1.488 (5.489)
Recall: Long, 7 day * asset index	-3.307 (5.173)	14.48*** (4.441)	10.21*** (2.565)	-0.630 (14.16)	-6.936 (40.84)	2.127 (1.579)	-8.004* (4.712)	7.533 (6.402)	-0.779 (5.635)
Recall: Subset, 7 day * asset index	-14.41*** (5.151)	7.739* (4.422)	8.814*** (2.554)	-32.91** (14.10)	-96.45** (40.67)	-0.506 (1.573)	-17.16*** (4.693)	14.76** (6.376)	-13.47** (5.612)
VARIABLES	(10) Vitamin A	(11) Vitamin B1	(12) Vitamin B2	(13) Vitamin B3	(14) Vitamin B6	(15) Vitamin B9	(16) Vitamin B12	(17) Vitamin C	(18) Vitamin E
Diary: HH frequent * asset index	-17.12 (11.13)	-2.393 (3.901)	-21.30* (12.05)	-4.454 (4.423)	-4.132 (6.553)	-2.820 (4.931)	-29.74** (13.13)	-2.371 (8.405)	5.280 (6.992)
Diary: HH infrequent * asset index	-15.07 (11.14)	-2.194 (3.906)	-24.99** (12.06)	-3.867 (4.429)	-3.452 (6.561)	-3.301 (4.938)	-22.35* (13.14)	-3.866 (8.416)	5.013 (7.001)
Recall: Long, 14 day * asset index	-5.204 (10.94)	-1.125 (3.837)	9.693 (11.85)	3.527 (4.351)	3.742 (6.445)	4.751 (4.850)	-23.62* (12.91)	7.945 (8.266)	-4.988 (6.876)
Recall: Long, 7 day * asset index	5.971 (11.24)	-4.253 (3.940)	-0.393 (12.17)	4.817 (4.467)	-1.605 (6.617)	2.612 (4.980)	-6.621 (13.25)	-1.326 (8.487)	-8.014 (7.060)
Recall: Subset, 7 day * asset index	2.903 (11.19)	-8.694** (3.923)	-1.886 (12.12)	-1.772 (4.449)	-8.762 (6.590)	0.595 (4.959)	10.09 (13.20)	-18.09** (8.452)	8.660 (7.031)
VARIABLES	(19) Calcium	(20) Phosphorous	(21) Iron	(22) Sodium	(23) Potassium	(24) Magnesium	(25) Zinc		
Diary: HH frequent * asset index	-1.751 (2.292)	-6.687 (6.053)	-3.138 (4.277)	0.221 (2.243)	-2.372 (5.973)	-2.794 (5.368)	-2.368 (3.193)		
Diary: HH infrequent * asset index	1.637 (2.295)	-3.218 (6.061)	-3.737 (4.283)	0.527 (2.246)	-1.912 (5.981)	-3.706 (5.375)	-2.971 (3.197)		
Recall: Long, 14 day * asset index	10.70*** (2.255)	6.881 (5.953)	3.133 (4.206)	14.23*** (2.206)	-1.712 (5.875)	-11.99** (5.280)	-2.271 (3.140)		
Recall: Long, 7 day * asset index	12.49*** (2.315)	9.689 (6.113)	2.438 (4.319)	19.08*** (2.265)	-6.127 (6.032)	-13.47** (5.421)	0.805 (3.224)		
Recall: Subset, 7 day * asset index	6.391*** (2.305)	0.261 (6.088)	-2.678 (4.301)	-1.974 (2.255)	-13.88** (6.007)	-17.90*** (5.399)	-0.0263 (3.211)		

Table A4 | Interaction terms between module type and share of children below 6 years old

VARIABLES	(1) Calories	(2) Protein	(3) Animal protein	(4) Fat	(5) Saturated fat	(6) Cholesterol	(7) Carbohydrates	(8) Sugars	(9) Fibre
Diary: HH frequent * share children below 6	10.37 (30.58)	19.30 (26.52)	5.717 (15.53)	12.83 (84.07)	23.65 (242.4)	1.348 (9.832)	17.77 (27.86)	-11.78 (38.17)	29.66 (33.60)
Diary: HH infrequent * share children below 6	15.94 (30.52)	22.70 (26.46)	7.968 (15.49)	41.66 (83.88)	66.53 (241.8)	5.095 (9.811)	10.26 (27.80)	0.172 (38.09)	19.11 (33.53)
Recall: Long, 14 day * share children below 6	-12.05 (30.20)	-35.37 (26.19)	-18.29 (15.33)	-4.320 (83.01)	2.132 (239.3)	-11.10 (9.708)	-16.66 (27.51)	5.108 (37.69)	-18.45 (33.17)
Recall: Long, 7 day * share children below 6	-30.93 (30.66)	-64.69** (26.59)	-31.29** (15.57)	-2.360 (84.28)	12.26 (243.0)	-19.29* (9.857)	-50.08* (27.93)	-18.75 (38.27)	-54.83 (33.68)
Recall: Subset, 7 day * share children below 6	6.824 (29.73)	-21.79 (25.78)	-22.49 (15.09)	96.54 (81.72)	246.8 (235.6)	1.003 (9.557)	-31.79 (27.09)	-34.12 (37.11)	-16.22 (32.66)
VARIABLES	(10) Vitamin A	(11) Vitamin B1	(12) Vitamin B2	(13) Vitamin B3	(14) Vitamin B6	(15) Vitamin B9	(16) Vitamin B12	(17) Vitamin C	(18) Vitamin E
Diary: HH frequent * share children below 6	29.27 (67.01)	28.81 (23.51)	64.79 (72.04)	29.59 (26.29)	19.22 (39.15)	10.71 (29.28)	-35.75 (84.35)	35.12 (50.17)	-19.91 (41.68)
Diary: HH infrequent * share children below 6	55.25 (66.86)	15.52 (23.46)	7.293 (71.88)	41.05 (26.23)	13.20 (39.07)	4.807 (29.21)	28.56 (84.16)	-3.807 (50.06)	-27.97 (41.59)
Recall: Long, 14 day * share children below 6	15.61 (66.16)	-19.28 (23.21)	-3.571 (71.13)	-11.01 (25.96)	-21.72 (38.66)	-40.52 (28.91)	-16.54 (83.28)	-29.97 (49.54)	3.548 (41.15)
Recall: Long, 7 day * share children below 6	-73.52 (67.17)	-44.21* (23.57)	-33.71 (72.22)	-39.98 (26.36)	-81.35** (39.25)	-69.36** (29.35)	-30.72 (84.56)	-107.7** (50.30)	65.00 (41.78)
Recall: Subset, 7 day * share children below 6	-110.7* (65.13)	-26.98 (22.85)	-43.94 (70.02)	-4.036 (25.56)	-84.37** (38.06)	-57.67** (28.46)	23.02 (81.99)	-102.4** (48.77)	54.60 (40.52)
VARIABLES	(19) Calcium	(20) Phosphorous	(21) Iron	(22) Sodium	(23) Potassium	(24) Magnesium	(25) Zinc		
Diary: HH frequent * share children below 6	-0.842 (13.82)	27.44 (36.03)	20.52 (25.45)	-7.505 (14.15)	17.75 (36.03)	22.25 (32.16)	4.991 (19.35)		
Diary: HH infrequent * share children below 6	-8.966 (13.79)	25.48 (35.95)	15.71 (25.40)	-6.095 (14.12)	12.32 (35.95)	25.76 (32.09)	11.22 (19.30)		
Recall: Long, 14 day * share children below 6	-33.43** (13.65)	-50.62 (35.57)	-30.24 (25.13)	-48.17*** (13.97)	-1.332 (35.57)	3.433 (31.76)	-23.12 (19.10)		
Recall: Long, 7 day * share children below 6	-44.00*** (13.86)	-86.74** (36.12)	-46.27* (25.52)	-50.06*** (14.19)	-38.62 (36.12)	-28.54 (32.24)	-40.52** (19.39)		
Recall: Subset, 7 day * share children below 6	-37.97*** (13.44)	-43.25 (35.02)	-15.50 (24.74)	-0.296 (13.76)	-72.07** (35.02)	-0.154 (31.26)	1.583 (18.81)		

Table A5 | Interaction terms between module type and households living in urban regions

VARIABLES	(1) Calories	(2) Protein	(3) Animal protein	(4) Fat	(5) Saturated fat	(6) Cholesterol	(7) Carbohydrates	(8) Sugars	(9) Fibre
Diary: HH frequent * urban hh	-11.17 (10.75)	-17.92* (9.239)	-11.13** (5.425)	-20.69 (29.37)	-48.49 (84.84)	-8.195** (3.410)	-7.309 (9.712)	6.834 (13.54)	-10.24 (11.76)
Diary: HH infrequent * urban hh	-10.33 (10.76)	-14.33 (9.248)	-6.723 (5.430)	-25.23 (29.39)	-56.82 (84.92)	-8.062** (3.414)	-7.451 (9.721)	-1.195 (13.55)	-9.335 (11.78)
Recall: Long, 14 day * urban hh	-32.99*** (10.74)	-0.385 (9.228)	13.59** (5.418)	-26.98 (29.33)	-56.42 (84.74)	3.065 (3.406)	-44.57*** (9.700)	-1.306 (13.52)	-24.42** (11.75)
Recall: Long, 7 day * urban hh	-25.35** (10.74)	12.60 (9.228)	14.10*** (5.418)	-6.399 (29.33)	-17.34 (84.74)	2.964 (3.406)	-42.05*** (9.700)	-2.167 (13.52)	-16.06 (11.75)
Recall: Subset, 7 day * urban hh	-17.40 (10.74)	-6.289 (9.228)	14.21*** (5.418)	31.99 (29.33)	122.5 (84.74)	0.904 (3.406)	-60.31*** (9.700)	6.096 (13.52)	-58.45*** (11.75)
VARIABLES	(10) Vitamin A	(11) Vitamin B1	(12) Vitamin B2	(13) Vitamin B3	(14) Vitamin B6	(15) Vitamin B9	(16) Vitamin B12	(17) Vitamin C	(18) Vitamin E
Diary: HH frequent * urban hh	-33.11 (23.65)	-9.422 (8.212)	-20.20 (25.30)	-17.95* (9.239)	-10.57 (13.56)	-7.286 (10.30)	-71.59** (28.77)	-8.506 (17.37)	13.29 (14.65)
Diary: HH infrequent * urban hh	-42.61* (23.68)	-7.987 (8.220)	-49.19* (25.32)	-13.45 (9.248)	-9.951 (13.57)	-15.68 (10.31)	-64.34** (28.80)	-15.86 (17.38)	18.17 (14.67)
Recall: Long, 14 day * urban hh	-40.11* (23.63)	-33.51*** (8.202)	3.368 (25.27)	-25.35*** (9.228)	-33.77** (13.54)	-14.75 (10.28)	-43.71 (28.73)	-28.88* (17.35)	13.76 (14.64)
Recall: Long, 7 day * urban hh	-27.36 (23.63)	-31.12*** (8.202)	-0.0773 (25.27)	-16.26* (9.228)	-44.08*** (13.54)	-17.60* (10.28)	-42.74 (28.73)	-30.34* (17.35)	-0.702 (14.64)
Recall: Subset, 7 day * urban hh	-52.76** (23.63)	-44.22*** (8.202)	-13.68 (25.27)	-39.54*** (9.228)	-50.61*** (13.54)	-34.43*** (10.28)	3.258 (28.73)	-68.95*** (17.35)	40.99*** (14.64)
VARIABLES	(19) Calcium	(20) Phosphorous	(21) Iron	(22) Sodium	(23) Potassium	(24) Magnesium	(25) Zinc		
Diary: HH frequent * urban hh	-3.511 (4.846)	-19.28 (12.67)	-10.95 (8.948)	-2.359 (4.829)	-8.101 (12.14)	-7.234 (11.23)	-7.673 (6.676)		
Diary: HH infrequent * urban hh	1.330 (4.850)	-11.71 (12.68)	-11.28 (8.956)	-3.076 (4.834)	-9.472 (12.15)	-12.47 (11.24)	-10.25 (6.682)		
Recall: Long, 14 day * urban hh	14.75*** (4.840)	-22.07* (12.66)	-26.08*** (8.937)	23.71*** (4.824)	-38.84*** (12.13)	-40.37*** (11.22)	-8.863 (6.668)		
Recall: Long, 7 day * urban hh	19.94*** (4.840)	-4.510 (12.66)	-18.96** (8.937)	37.74*** (4.824)	-53.04*** (12.13)	-36.57*** (11.22)	1.814 (6.668)		
Recall: Subset, 7 day * urban hh	5.667 (4.840)	-32.25** (12.66)	-33.61*** (8.937)	-4.437 (4.824)	-71.73*** (12.13)	-61.21*** (11.22)	-8.919 (6.668)		

Table A6 | Cost of basic needs food poverty

A: Percentage of households spending below threshold						
	Dodoma	Pwani	Dar es Salaam	Shinyanga	Kagera	Total
Diary: Personal	23.22	48.69	53.30	43.06	47.78	43.75
Diary: HH, frequent	43.95	70.30	76.81	60.04	53.74	60.05
Diary: HH, infrequent	31.11	68.21	65.51	51.13	57.52	54.43
Recall: Long, 14 day	39.80	63.02	45.56	76.58	56.47	61.64
Recall: Long, 7 day	25.09	53.08	30.21	57.18	50.53	47.38
Recall: Subset, 7 day	36.41	48.80	44.84	68.74	46.69	53.25
B: Average poverty gap of the food-poor						
	Dodoma	Pwani	Dar es Salaam	Shinyanga	Kagera	Total
Diary: Personal	30.80	42.15	31.52	31.38	27.56	31.76
Diary: HH, frequent	35.01	33.56	38.29	34.07	32.73	34.43
Diary: HH, infrequent	28.46	37.26	42.70	30.36	29.37	32.92
Recall: Long, 14 day	23.22	31.86	32.48	38.28	40.68	36.37
Recall: Long, 7 day	25.44	30.02	28.30	35.18	29.99	31.74
Recall: Subset, 7 day	36.04	30.70	27.25	37.56	28.81	33.47