Measuring Access to Nutritious Diets in Africa:

Novel Price Indexes for Diet Diversity and the Cost of Nutrient Adequacy

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Abstract

Policies and programs often aim to improve the affordability of nutritious diets, but existing food price indexes are based on observed quantities which may not meet nutritional goals. To measure changes in the cost of reaching international standards of diet quality, we introduce a new Cost of Diet Diversity index based on consuming at least five different food groups as defined by the widely-used Minimum Dietary Diversity for Women (MDD-W) indicator, and compare those results with the cost of foods needed to meet adult women's estimated average requirements of essential nutrients and dietary energy. Using national average monthly market price data for Ghana from 2009 through 2014, we find that the relative cost of reaching the MDD-W standard fluctuates seasonally and since mid-2010 has risen about 10 percent per year faster than inflation due to rising relative prices for fruit and fish, while the cost of nutrient adequacy rose even faster due primarily to increased cost of foods rich in vitamin A and calcium. Similar data for Tanzania from 2011 through 2015 show small increases in 2011 and 2012 but stable prices thereafter. Our methods can show where and when nutritious diets are increasingly (un)affordable, and which nutritional criteria account for the change. These results are based on national price monitoring systems, but the method is generalizable to other contexts for monitoring, evaluation, and assessment of changing food environments.

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Motivation

Price indexes for traded commodities are widely reported by international agencies such as the Food and Agricultural Organization (FAO 2017), while local wholesale and retail prices are collected and used in almost all countries to monitor producer prices, market conditions, overall inflation and living standards (World Bank 2017a, 2017b). Formulas to aggregate individual items into price indexes were first introduced more than 300 years ago (Diewert 1993), with continued changes needed to reflect what and how goods and services are consumed (Diewert, Greelees and Hulten 2010, Rippy 2014).

The purpose of most price indexes is to capture changes in the cost of what is actually bought and sold, which can vary greatly in nutritional quality over time and across groups (Beatty, Lin and Smith 2014; Clements and Si 2017). To make nutritious diets more affordable, policies and programs may aim to lower the relative cost of more nutritious foods, and sometimes also raise the cost of less healthy items. The aim of this paper is to develop improved indexes for the cost of a nutritious diet relative to other prices in the African context, where healthier foods such as dairy, eggs, fruits and vegetables are often out of reach (Green *et al.*, 2013) especially for low-income net food buyers in high-cost areas (Harttgen, Klasen and Rischke, 2016).

The oldest approach to measuring affordability of a healthy diet is the cost of nutrient adequacy. Soon after essential nutrients were first discovered, Stigler (1945) developed linear programming methods for calculating how much of each food would be needed to meet recommended intake of each required nutrient at lowest total cost. A few papers use these least-cost diets to track the cost of nutrients over time (O'Brien-Place and Tomek 1983, Hakansson 2015, Omiat and Shively 2017), make comparisons across countries (Chastre *et al*. 2007) or compare actual choices to least-cost diets within a country (Maillot *et al.* 2017), but the method is most often used for the purpose of making nutritional recommendations to low-income consumers. At the United States Department of Agriculture (USDA), the "Minimum-Cost Food Plan" proposed for people facing extreme poverty during the depression of the 1930s (Cofer *et* *al.*1962) evolved with the use of linear programming into the Thrifty Food Plan (TFP) to calculate and justify the amount of money provided in food stamps and supplemental nutrition assistance for low-income Americans (USDA 2017). The same method is used internationally, for example to make recommendations in Denmark (Parlesak et al. 2016), and improve methods to accommodate palatability constraints in the Netherlands (Gerdessen and De Vries 2015), with one of the most important uses being to help nutrition-assistance programs meet specific needs of children and other vulnerable groups, as in the *Cost-of-the-Diet* approach developed by Save the Children UK and others (Chastre et al. 2007, Deptford et al. 2017), and *Optifood* developed by the London School of Hygiene and Tropical Medicine and others (Optifood 2012, Vossenaar 2017).

Our aim in this paper is to extend the literature on food price indexes beyond nutrients to diversity among food groups. Consuming foods from a several different categories has long been seen as desirable, leading to a major international effort to standardize diet diversity measurement especially for infants and women at risk of malnutrition. For infants and young children aged 6-23 months, the World Health Organization (WHO) and the United Nations Children's Fund (UNICEF) use a Minimum Dietary Diversity indicator defined as consuming four out of seven specific food groups in the previous day or night (WHO and UNICEF 2007, UNICEF 2016). For adult women of reproductive age, the Food and Agricultural Organization (FAO) and FHI360 in a USAID-funded project have developed a benchmark Minimum Diet Diversity for Women (MDD-W) indicator, defined as consuming foods from at least five out of ten specific food groups during the previous day or night (Martin-Prevel et al. 2017, FAO and FHI360 2016). MDD-W has been linked to nutrient adequacy in several low-income countries (Arimond *et al.* 2010), and may confer additional health benefits associated with phytochemicals and other diet qualities in addition to nutrients (Shiraseb *et al.* 2016). Operationally, the MDD-W is particularly useful as a global standard for policy analysis and program management, since the number of food groups consumed in the past 24 hours can be measured quickly using a list-based method, whereas the volume of food consumed and its nutrient composition are much more difficult to quantify. Designing a food price index around this criterion allows us to determine whether meeting the MDD-W is increasingly (un)affordable for consumers at each time and place.

Methods

To track changes in the cost of nutritious diets with broad relevance for the adult population, we compute a price index defined around the MDD-W and compare that to the corresponding cost of nutrient adequacy, using monthly national average food prices in Ghana and Tanzania. We refer to the two measures as the Cost of Dietary Diversity (CoDD), defined as the least-cost foods needed to meet the MDD-W, and the Cost of Nutrient Adequacy (CoNA), defined as the least-cost foods needed to meet average nutrient requirements. Both are computed relative to all other prices in the local economy and converted to constant US dollars at purchasing-power parity (PPP) exchange rates. This provides comparable inflation-adjusted price indexes, measuring the cost of reaching these two nutritional standards relative to all other prices in the economy.

Our central innovation is to introduce a price index that aggregates foods in terms of dietary diversity, as defined for the MDD-W as the number of food groups included in the previous day's dietary intake. The MDD-W threshold is reached when foods from five or more groups are consumed. CoDD is defined as the least expensive way of acquiring some food from each group. To aggregate over groups, we provide two distinct measures: a lower-bound CoDD1 counts only the least-cost food in each of the five least expensive food groups, while a broader CoDD2 counts the average of the least-cost food in all food groups. CoDD1 reflects a narrow version of the MDD-W defined so that dietary diversity can be achieved with the same five food groups every day, while CoDD2 reflects a broader version in which consumers rotate among all food groups with equal frequency. We call these the Minimum Cost of Five Groups ("CoDD1") and the Minimum Cost of All Groups ("CoDD2"), formally defined as:

$$\text{CoDD1} = \text{min5}\{\min\{p_{i1}\}, \min\{p_{i2}\}, \dots, \min\{p_{im}\}\} \quad (1)$$

$$\text{CoDD2} = \text{ave}\{\min\{p_{i1}\}, \min\{p_{i2}\}, \dots, \min\{p_{im}\}\} \quad (2)$$

where min5 denotes the 5^{th} lowest of all m food groups, and p_{ij} is the price of item i in the j^{th} food group. There are a maximum of m=10 food groups, but due to missing data, m=8 in Ghana and 10 in Tanzania. By definition, the MDD-W indicator and hence CoDD price indexes make no reference to quantities consumed. Also by definition only the least-cost food within each group is included, so the foods included in CoDD are not necessarily a positive description of what people actually consume or a normative prescription for what they should consume. Instead, CoDD1 provides a lower bound on the cost of foods from five groups to meet the MDD-W threshold, while CoDD2 provides a lower bound on the cost of acquiring some food from each MDD-W food group, thereby tracking changes in access to foods needed to meet the nutritional standard specified by MDD-W.

As a benchmark for comparison we use the same data to compute the cost of nutrient adequacy (CoNA), defined as the minimum cost of foods that meet all known requirements for essential nutrients and dietary energy requirements for an adult woman of reproductive age. CoNA can be written formally as:

$$\textit{CoNA}\text{: minimize } C = \sum_i p_i \times q_i \qquad (3)$$

Subject to:

$$\sum_i a_{ij} \times q_i \geq EAR_i \text{ (j=1,2,3,…,n)} \qquad (4)$$

$$\sum_i a_{ie} \times q_i = E \qquad (5)$$

$$q_1 \geq 0,\ q_2 \geq 0,\ \dots,\ q_i \geq 0 \qquad (6)$$

Here, the quantity of the j^{th} nutrient in food i is denoted a_{ij}, which multiplied by its quantity consumed (q_i) must meet the population's estimated average requirement (*EAR*) for nutrient j, at lowest total cost given all prices (p_i) within the further constraint of overall energy balance (E) which for convenience we set at 2,000 kcal/day. There are 21 known essential nutrients but for nutritional adequacy we drop vitamin D and cholesterols which can be synthesized in human bodies, and iodine and molybdenum due to lack of data in the food composition databases, leaving n=17 nutrient constraints plus a constraint for energy balance. This computation provides a lower bound on the cost of meeting the EARs, allowing us to track changes in the cost of limiting nutrients much as the CoDD tracks changes in the cost of limiting foods.

For both CoDD and CoNA we report which foods would be needed to meet each nutritional constraint at lowest cost, thereby tracking changes in access to that nutritional standard. By defining ‘access’ to mean a lower bound on total cost, these price indexes deliberately differ from what any group might *actually* consume (for which we would use a consumption price index), or *should* consume (in the sense of a recommended diet). As described in the discussion section, parallel work is under way to construct nutritionally-weighted consumer price indexes (nCPI) that would reflect nonmarket (dis)utilities from the foods actually consumed, and to construct globally relevant cost of a recommended diet (CoRD) indexes that would reflect normative dietary guidelines published by national or international agencies.

The focus of CoNA is the cost of nutrients, which is reflected in their shadow prices (*SP*) defined as the cost increase associated with increasing each constraint by one unit:

$$SP_j = \frac{\partial C^*}{\partial EAR_j^+} \tag{7}$$

Where C^* denotes the (minimum) cost of the CoNA diet. SP_j is the *SP* of nutrient *j* (or daily dietary energy), and EAR_j^+ refers one unit increase in EAR of nutrient *j* (or daily dietary energy). Since units of measure for nutrients may differ, we construct a semi-elasticity denoted SP' as increment in cost of the CoNA diet when the constraint is increased by 1%, expressed as:

$$SP_j' = \frac{\partial C^*}{\%\Delta EAR_j^+} \tag{8}$$

The sum of SP'_j ($\sum_j SP'_j$ or SP') of all 17 nutrients and dietary energy equals to the change of CoNA when all nutritional and energy constraints are increased by 1% together. For ease of comparison with CoNA itself we report *SP’* multiplied by 100, which we refer to as the shadow price contribution (SPC) of nutrient *j* or dietary energy:

$$SPC_j = SP_j' \times 100 \tag{9}$$

Similarly, we further calculated the Shadow Price Elasticity (SPE) of nutrient *j* defined as the percentage change of the cost of the CoNA diet package evaluated at the optimal basis in response of 1% increase in EAR of nutrient *j*.

$$SPE_j = \frac{\%\Delta C^*}{\%\Delta EAR_j^+} \tag{10}$$

The SPE is useful to identify the limiting nutrients for which the level of EAR contributes the most to CoNA at each time and place. It measures the change in total cost associated with a marginal change in each nutrient requirement, thereby revealing the degree to which that particular requirement accounts for differences in the cost of acquiring all essential nutrients.

Calculations for all equations were completed in R and resulting index values exported to Stata or Excel for visualization purposes, with model code and data for replication posted online at the project website referenced in this paper's acknowledgements.

Data

Our empirical application draws on four main data sources. Food price data are national average monthly food prices in Ghana between March 2009 and December 2014, and in Tanzania between January 2011 and December 2015. These were collected by national authorities and cover a total of 34 distinct foods in Ghana and 71 in Tanzania. Prices for each item are unweighted averages over a variety of retail markets, covering all 10 regions of Ghana and all 21 regions of mainland Tanzania. Primary data collection was conducted by the Ministry of Food and Agriculture (MoFA) in Ghana for their market information system, and by the National Bureau of Statistics (NBS) in Tanzania for the purpose of inflation monitoring. In this paper we deliberately use data with different institutional origins to show the range of applicability for these indexes, recognizing that differences between countries also reflect differences in data-collection methods. There were no missing values in the Tanzania data, but for Ghana there are missing observations for soybean (Feb 2010) and mango (Aug, Sep and Oct 2009; Feb 2011; Sep and Oct 2013). To complete the dataset for results shown here we impute prices by carry-over from the previous month. This method is unlikely to truncate seasonal extremes, as mangoes in Ghana generally mature between May and August, with some varieties in southern Ghana also maturing between December and February (MoFA 2017).

To compute the price indexes, the price of each food was converted from reported units, such as price per dozen eggs, to cost per unit of weight and/or of dietary energy of the edible portion, and then converted to a common currency and adjusted for inflation by purchasing-power-parity (PPP) conversion factor provided by the World Bank (2016). We excluded most processed foods and classified foods into one of ten mutually exclusive food groups based on the FAO and FHI360 (2016) guidelines for calculating MDD-W: 1) Grains, white roots and tubers, and plantains, 2) Pulses, 3) Nuts and seeds, 4) Dairy, 5) Meat, poultry and fish, 6) Eggs, 7) Dark green leafy vegetables, 8) Vitamin A-rich fruits and vegetables, 9) Other vegetables, and 10) Other fruits. Additional foods that people might consume are not included in the MDD-W calculation, notably oils and fats, sweets and other foods, beverages other than dairy, condiments and seasonings. The available price data for Ghana cover 26 foods from eight of the ten MDD-W food groups, and price data for Tanzania cover 46 foods from all ten groups. The missing food groups in Ghana are dairy and dark green leafy vegetables. By definition, cooking oil is not included in the MDD-W or CoDD, but we do include it as a source of dietary energy for CoNA.

Additional data required for the calculation of CoNA include the nutrient composition and edible portions of each food as purchased, obtained from the two standard sources: FAO's West African Food Composition Table (Stadlmayr *et al.* 2012), complemented by the U.S. National Nutrient Database for Standard Reference (USDA 2013). Detailed food lists with nutrients compositions for both countries are presented in appendix Table A4 and A5. Nutrient requirements are obtained from the Estimated Average Requirements (EARs) for adult women from 19 to 30 years old, as specified in Dietary Reference Intakes (DRIs) developed by the U.S. Institute of Medicine of the National Academies. EAR, defined as the average daily nutrient intake level estimated to meet requirements at least half of the healthy individuals in a group, is the primary reference point for assessing the adequacy of estimated nutrient intakes of groups, and is a tool for planning intakes for groups (Institute of Medicine, 2006). A detailed table with energy and nutrients criteria is presented in appendix table A3.

Results

Descriptive statistics for prices per unit of dietary energy are summarized in Tables 1 and 2. The underlying descriptive statistics for prices per unit of weight are provided in the annex Tables A3 and A4.

For Ghana, we have a total of 70 monthly observations from March 2009 to December 2014 for 25 items, and 56 monthly observations from May 2010 to December 2014 for paddy rice. Of these, 12 food items are in the starchy staple group, reflecting the strong focus of data collection efforts on that category. The average price of each item per 1,000 kcal ranges widely, from \$0.26 for maize to \$20.77 for tomatoes, while prices per kg range from \$0.53 for cassava to \$8.90 for eggs shown in Table A1. The volatility of food prices over time, as represented by Coefficient of Variation (CV), varies widely from 0.07 for eggs to 0.36 for mangoes.

Table 1. Descriptive Statistics for Monthly Food Prices per 1,000 kcal – Ghana (2011$)

Food Groups	No	Foodstuffs	Obs.	Mean	Std. Dev.	CV	Min	Max
Grains, white roots and tubers, and plantains	1	Cassava	70	0.33	0.07	0.20	0.23	0.48
	2	Cocoyam	70	1.07	0.24	0.23	0.71	1.62
	3	Kokonte[3]	70	0.38	0.06	0.17	0.27	0.54
	4	Garri[3]	70	0.44	0.07	0.17	0.34	0.72
	5	Imported Rice	70	0.73	0.12	0.16	0.60	1.09
	6	Local Rice	70	0.52	0.06	0.12	0.42	0.75
	7	Maize	70	0.26	0.05	0.18	0.19	0.40
	8	Millet	70	0.39	0.05	0.13	0.31	0.51
	9	Paddy Rice	56	0.40	0.13	0.32	0.24	0.86
	10	Plantains	70	1.47	0.49	0.33	0.91	3.38
	11	Sorghum	70	0.37	0.04	0.11	0.29	0.47
	12	Yam	70	1.04	0.17	0.16	0.76	1.48
Pulses	13	Cowpea	70	0.61	0.10	0.17	0.43	0.85
	14	Soya Beans	70	0.29	0.07	0.24	0.13	0.47
Nuts & seeds	15	Groundnut[4]	70	0.58	0.11	0.19	0.40	0.79
Meat, poultry and fish	16	Anchovies	70	4.83	1.04	0.22	2.43	8.92
	17	Salted Dried Tilapia Fish	70	2.53	0.61	0.24	1.03	4.32
	18	Smoked Herrings	70	1.99	0.45	0.22	1.27	3.45
Eggs	19	Eggs	70	6.23	0.44	0.07	5.22	7.58
Vitamin A-rich vegetables and fruits	20	Mangoes	70	1.41	0.51	0.36	0.64	2.94
	21	Tomatoes	70	20.77	6.88	0.33	10.09	39.91
Other vegetables	22	Garden Eggs (egg plants)	70	9.16	2.37	0.26	4.78	16.55
	23	Large Onions	70	8.95	2.90	0.32	4.20	14.51
Other fruits	24	Bananas	70	1.90	0.37	0.20	1.15	2.84
	25	Oranges	70	2.94	0.90	0.31	1.20	6.72
	26	Pineapples	70	2.94	0.32	0.11	2.29	3.87

Note: Authors' calculations, from Ghana Ministry of Food and Agriculture data. Two food groups in the MDD-W are not represented in this dataset: Dairy, and Dark Green Leafy Vegetables. Kokonte and Gari are processed cassava products. Groundnuts are shelled, and prices for unshelled groundnut were removed in the data analysis. Data for soyabeans and mangoes include a total of seven imputed values as detailed in the text.

For Tanzania, we have a total of 60 monthly observations over 5 years from January 2011 to December 2015 for 46 items spanning 10 food groups as the final data base for index calculation. Starchy staples group, as the largest food group in terms of the number of food items, contains 10 items. Average prices per 1,000 kcal range from $0.31 for white maize to $24.78 for green peas, and prices per kg range from $1.11 for white maize to $39.56 for powered milk. The volatility of prices ranges from a CV of 0.02 for beef sausage and goat meat to 0.18 for limes.

Table 2. Descriptive Statistics for Monthly Food Prices per 1,000 kcal–Tanzania (2011$)

Food Group	No	Foodstuff	Obs.	Mean	Std. Dev.	CV	Min	Max
Grains, white roots and tubers, and plantains	1	Cassava flour	60	0.60	0.07	0.11	0.48	0.79
	2	Cassava fresh	60	0.77	0.07	0.09	0.60	0.90
	3	Cooking Bananas Green	60	1.64	0.09	0.05	1.45	1.90
	4	Finger millet	60	0.68	0.11	0.17	0.50	0.87
	5	Maize Flour	60	0.47	0.06	0.12	0.37	0.63
	6	Potatoes – round	60	2.25	0.13	0.06	1.97	2.63
	7	Rice	60	0.74	0.12	0.16	0.57	0.98
	8	Sweet Potatoes	60	1.70	0.14	0.08	1.46	1.97
	9	Wheat Flour	60	0.62	0.04	0.06	0.56	0.71
	10	White Maize	60	0.31	0.04	0.12	0.24	0.41
Pulses	11	Beans (soya)	60	0.65	0.03	0.04	0.59	0.70
	12	Lentils	60	1.28	0.12	0.09	1.08	1.48
	13	Red dry beans	60	0.78	0.04	0.05	0.72	0.87
Nuts & seeds	14	Natural Groundnuts	60	0.66	0.05	0.08	0.58	0.78
Dairy	15	Fresh cow milk	60	2.89	0.16	0.05	2.38	3.07
	16	Powdered milk	60	7.99	0.38	0.05	7.02	8.72
Meat, poultry and fish	17	Beef sausage	60	4.32	0.08	0.02	4.18	4.54
	18	Beef with bones	60	3.92	0.19	0.05	3.47	4.43
	19	Beef without bones	60	1.11	0.04	0.04	1.01	1.26
	20	Dried sardines	60	5.99	0.46	0.08	5.12	6.91
	21	Goat meat	60	9.51	0.38	0.04	8.37	10.19
	22	Industrially bred live chicken	60	6.57	0.31	0.05	5.6	6.99
	23	Pork meat	60	3.17	0.28	0.09	2.45	3.63
	24	Traditionally bred live chicken	60	11.9	0.79	0.07	9.94	13.26

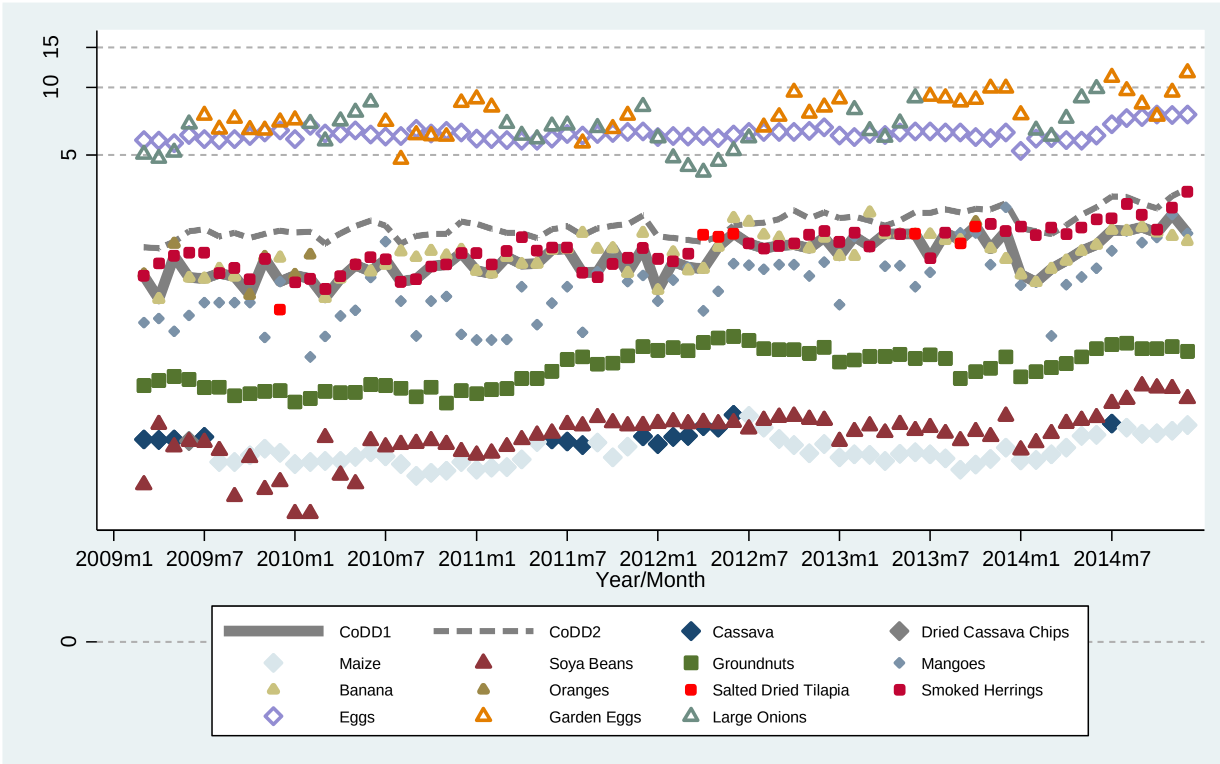
Table 2 (continued)

Food Group	No	Foodstuff	Obs.	Mean	Std. Dev.	CV	Min	Max
Eggs	25	Eggs-layers	60	8.42	0.28	0.03	7.89	8.88
	26	Eggs-traditional	60	11.81	0.69	0.06	10.3	12.66
Dark green leafy vegetables	27	Mchicha (spinach)	60	7.49	0.74	0.10	6.33	8.89
Vitamin A-rich vegetables and fruits	28	Carrots	60	7.05	0.69	0.10	6.01	9.08
	29	Mangoes	60	4.46	0.63	0.14	2.97	6.06
	30	Papaya	60	5.63	0.50	0.09	4.71	6.64
	31	Tomatoes red	60	10.44	1.19	0.11	8.36	13.53
Other vegetables	32	Bitter tomatoes	60	8.86	0.46	0.05	7.85	10.72
	33	Egg plant	60	9.44	0.49	0.05	8.47	10.83
	34	Cabbages	60	2.80	0.27	0.10	2.30	3.48
	35	Green peas	60	24.78	1.74	0.07	20.72	28.40
	36	Green bell pepper	60	16.46	0.92	0.06	14.78	19.16
	37	Ladies finger (okra)	60	11.28	0.75	0.07	9.97	13.25
	38	Onions	60	6.43	0.77	0.12	5.21	8.86
Other fruits	39	Apples (Imported)	60	19.58	1.62	0.08	15.85	23.62
	40	Avocado	60	1.91	0.12	0.06	1.67	2.18
	41	Coconut mature	60	5.52	0.51	0.09	4.78	6.85
	42	Lemons	60	11.75	2.03	0.17	8.26	17.99
	43	Limes	60	15.62	2.87	0.18	12.00	23.57
	44	Oranges	60	4.43	0.46	0.10	3.47	5.63
	45	Pineapples	60	6.66	0.65	0.10	5.54	7.98
	46	Sweet banana	60	3.35	0.28	0.08	2.71	3.91

Note: Authors' calculations, from Tanzania Bureau of Statistics data.

Turning to the CoDD indexes over all food groups, the following figure presents results for Ghana in terms of the individual foods that represent each group. It shows that the lowest-cost foods per unit of dietary energy are consistently starchy staples (maize and cassava), pulses (soybeans), nuts (groundnuts), vitamin A-rich vegetables and fruits (mangoes), and other fruits (bananas). Occasionally, some form of fish (salted dried tilapia or smoked herrings) becomes the fifth group. When the units are cost per kg, the results are similar, except that the "other vegetable" group (represented here by eggplants and onions) becomes cheaper than groundnuts due to its higher moisture content (see figures A1 in the Annex).

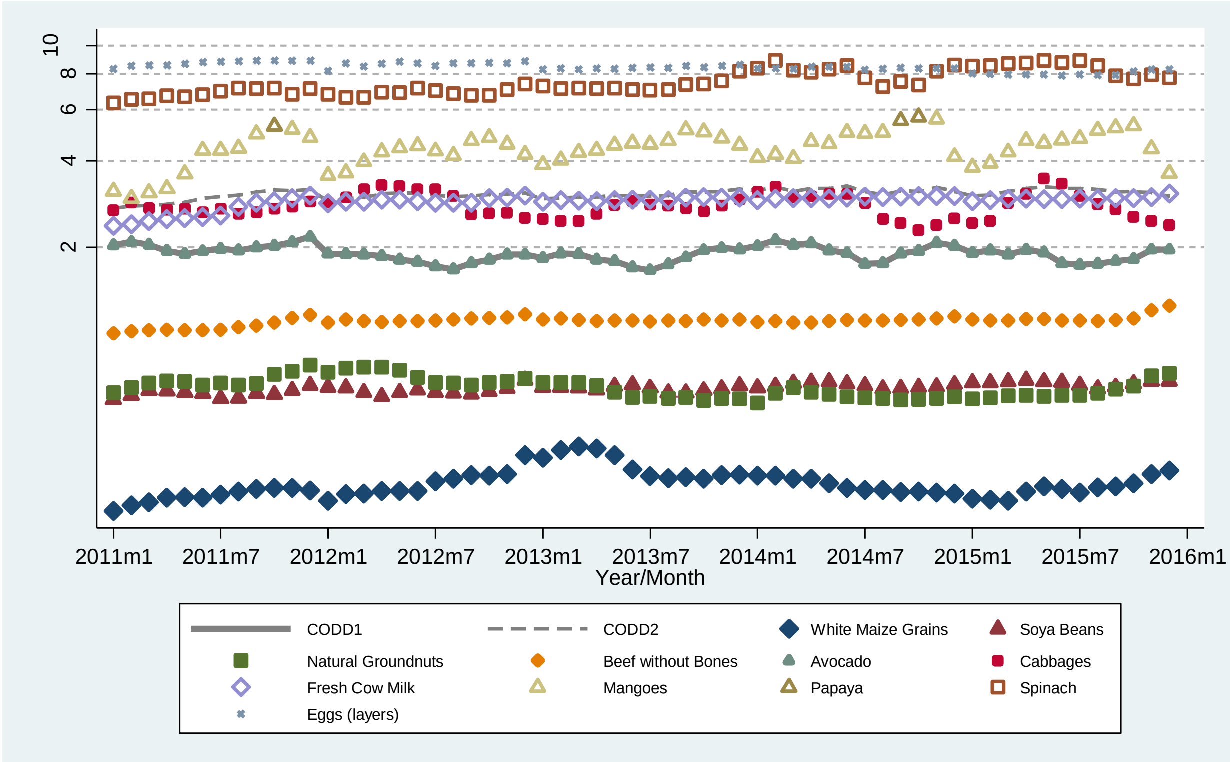
Figure 1. Cost of Diet Diversity in Ghana (least-cost foods to meet MDD-W, per 1,000kcal)



Results for Tanzania are presented in Figure 2, showing that the lowest-cost food groups per unit of dietary energy are consistently starchy staples (maize), pulses (soya bean), nuts and seeds (groundnuts), meats (beef) and other fruits (avocado). This figure reveals much more stability among the lower-cost food groups than among these foods in Ghana or relative to more expensive food groups in Tanzania. Such differences could reflect the type of market at which food prices are collected, as NBS in Tanzania aims to collect price data for inflation monitoring from the same sellers every time primarily in towns and cities, whereas MoFA in Ghana aims to collect price data for market information purposes from different sellers every time, in a wider variety and greater number of locations.

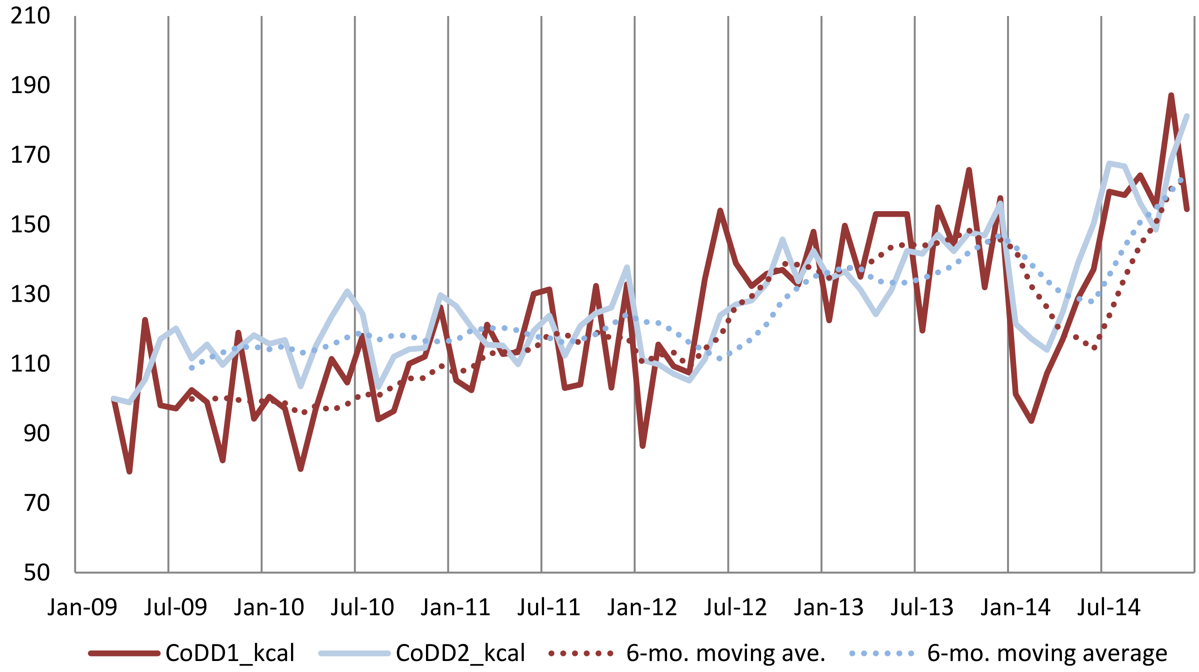
The relative cost of foods differs when the unit of comparison is cost per kg, rather than cost per 1,000kcal, due to large differences in moisture content and other influences on food weight. Figure A2 shows that when considering cost per kg, the lowest-cost food groups are starchy staples (maize and cassava), other vegetables (cabbage), dark green leafy vegetables (mchicha, or amaranth), vitamin A-rich fruits and vegetables (tomatoes), and dairy; per kg, eggs, groundnuts, and meats are the most expensive foods.

Figure 2. Cost of Diet Diversity in Tanzania (least-cost foods to meet MDD-W, per 1,000kcal)



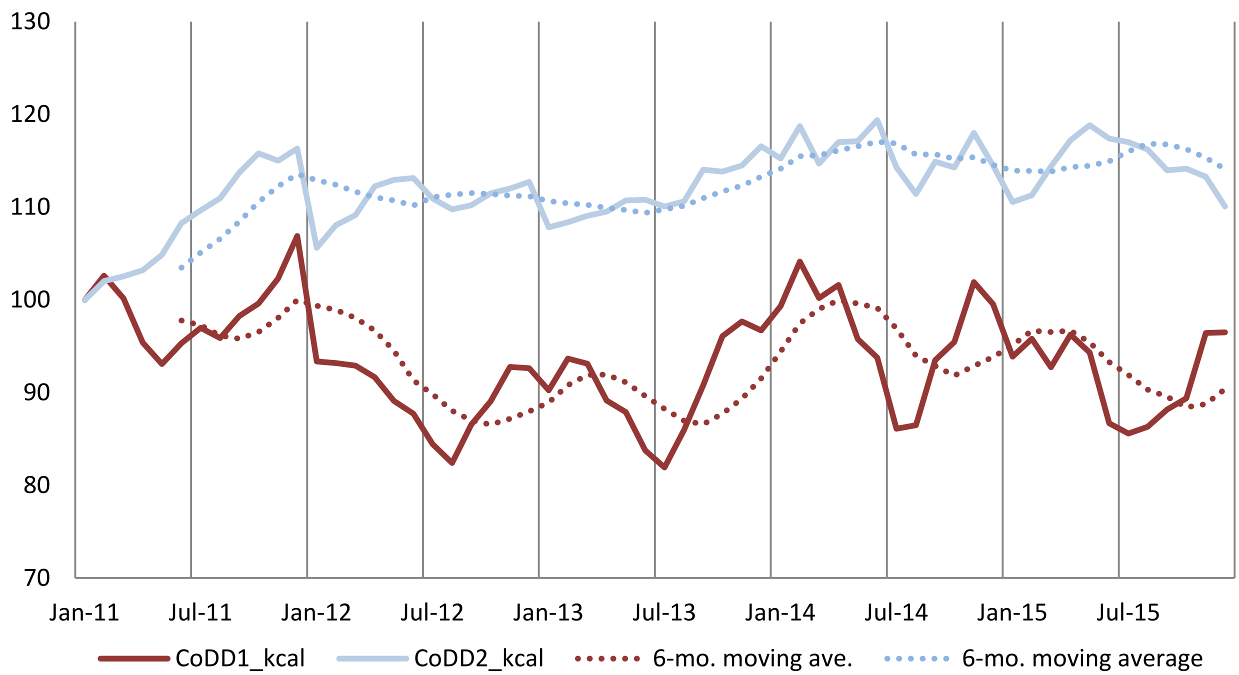
To reveal trends in each index, the final two figures show results of a 6-month moving average to smooth noise and seasonal fluctuations. These two countries had very different trends on the cost of nutritious diets. In Ghana, the two indexes rose 54 and 81 percentage points from the base period price of March 2009 to the end of 2014. In contrast, in Tanzania, CoDD1 dropped by 3 points and CoDD2 increased by 5 points from January 2011 to the end of 2015. It is also notable that the two CoDD indexes are very similar to each other in Ghana with correlation coefficient of 0.80, and much less so in Tanzania with correlation coefficient of only 0.07. In Ghana, prices for different food groups move together, while in Tanzania prices for the five least expensive groups differ greatly from the prices of more expensive foods.

Figure 3. CoDD indexes based on MDD-W criteria in Ghana (per 1,000kcal)



Note: Base period price of the indexes is the CoDD value of March 2009. Data imputation for Soya Beans and Mangoes.

Figure 4.CoDD indexes based on MDD-W criteria in Tanzania (per 1,000kcal)



Note: Base period price of the indexes is the CoDD value of January 2011.

Regarding the CoNA index, for Ghana the solution to equations (3) – (6) provides 70 monthly diet packages and their corresponding CoNA values. A total of eight distinct food items were ever included in those least-cost diets, of which three (mangoes, soybeans and smoked herrings) are included in every month. Mangoes and soybeans enter with mean intakes of 900 and 256 g/day respectively, as they are the principal sources of binding nutrients which are more costly to obtain from other sources in the Ghanaian context. Such a high level of consumption for these two foods is not a realistic or a recommended diet, but does reveal the degree to which the nutrient profile of mango and soybean fills gaps left by other foods listed in Table 3 below.

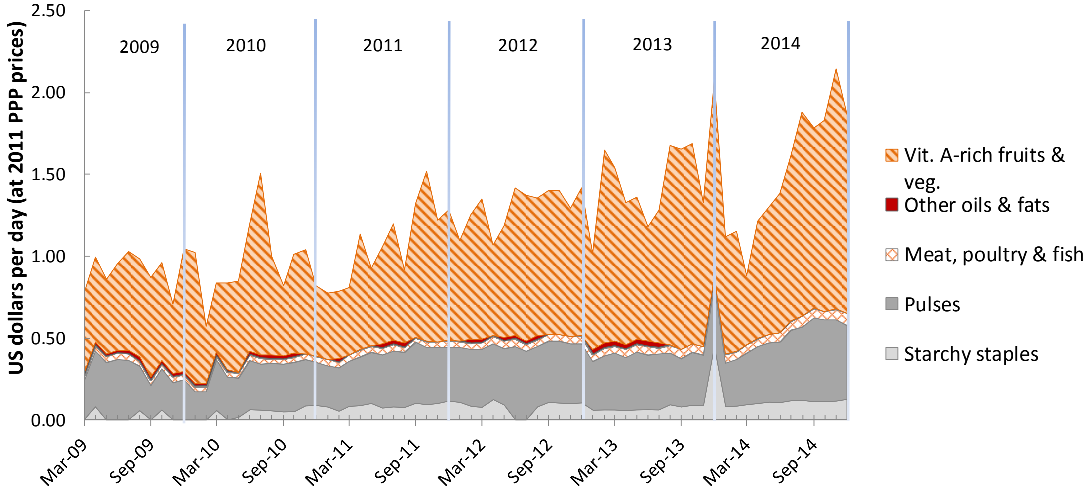
Table 3.Foods selected for CoNA diet plans in Ghana, Mar 2009-Dec 2014

Food Item	2009-2014		2009		2010		2011		2012		2013		2014	
	Mean	%Selected	Mean	%Selected	Mean	%Selected	Mean	%Selected	Mean	%Selected	Mean	%Selected	Mean	%Selected
Cassava	21	11%	18	10%	--	--	47	25%	63	33%	--	--	--	--
Maize	50	69%	14	20%	48	67%	55	75%	36	50%	66	92%	74	100%
Mangoes	900	100%	910	100%	904	100%	902	100%	905	100%	881	100%	899	100%
Paddy Rice	14	49%	--	--	6	25%	18	67%	13	50%	15	42%	27	100%
Palm Oil	4	51%	7	100%	6	75%	3	33%	4	50%	5	58%	--	--
Plantain	3	1%	--	--	--	--	--	--	--	--	19	8%	--	--
Smoked Herrings	15	100%	15	100%	15	100%	15	100%	15	100%	15	100%	15	100%
Soya Beans	256	100%	289	100%	267	100%	242	100%	252	100%	246	100%	243	100%

Note: Data shown are mean intake (g/day) and intake frequency (percent of days) for lowest-cost diets that reach the estimated average requirement (EAR) of essential nutrients for an adult woman of 55kg at an energy level of 2,000 kcal/day. Methods are as specified in text.

As shown in Figure 5, the CoNA index for Ghana more than doubled from USD 0.78 per day in March 2009 to USD 1.87 in December 2014. We can link the foods that account for this rise back to the food groups used for CoDD, noting that mangoes from the vitamin A-rich fruits and vegetables group accounted for more than 60% of CoNA on average. Soybeans from the pulses group contributed about 28% of CoNA on average, while cassava from the starchy staples group, and smoke herrings from the flesh-foods group accounted for approximately 6% and 4% respectively. The remaining cost was palm oil, which is not included in CoDD and which contributed about 1.5% of CoNA before July 2013, then not selected for least-cost diet packages thereafter.

Figure 5. CoNA for least-cost diet by food groups in Ghana, Mar 2009-Dec 2014



Note: Data shown are total cost in each month of the foods needed for lowest cost of nutrient adequacy (CoNA), for an adult woman of 55kg at a dietary energy level of 2000 kcal/day.

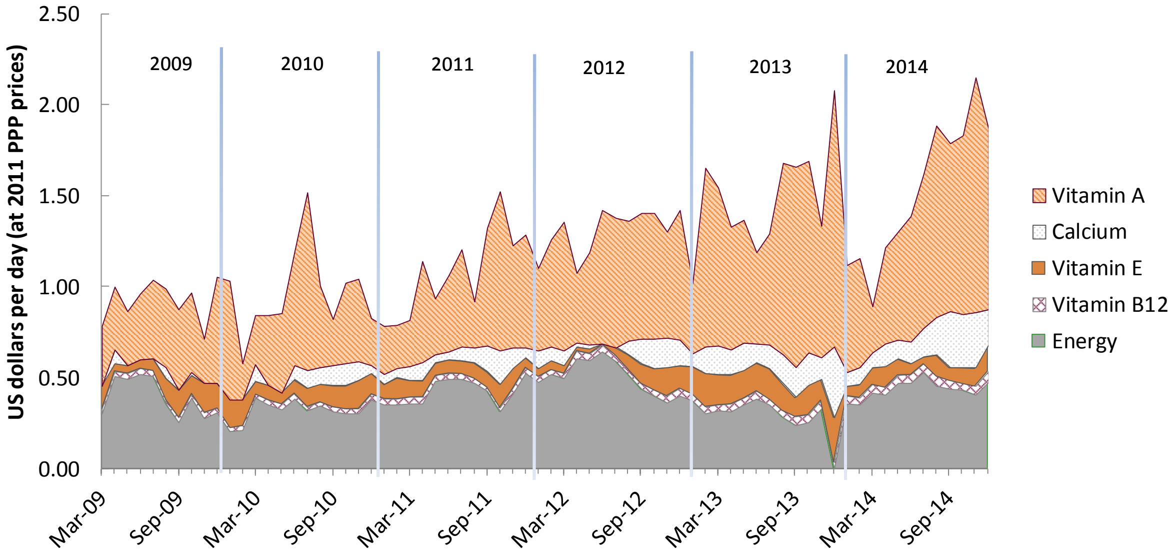
As shown in Table 4, in Ghana a total of five nutrients have limiting EARs, four of which were limiting nutrients in all months. Vitamin A, as the most expensive nutrient, has a shadow price elasticity (SPE) of 0.47, meaning that CoNA increases by 0.47% when the EAR for vitamin A increases by 1%, i.e. from 500 mcg to 505 mcg per day. Dietary energy is still a very important constraint in Ghana with an average SPE of 0.34. As shown in Figure 6, the nutrients that are most limiting for CoNA in Ghana are vitamin A, followed by dietary energy, vitamin E, calcium and vitamin B12.

Table 4. Nutrient requirements contributing to CoNA in Ghana, Mar 2009-Dec 2014

Nutrient	2009-2014		2009		2010		2011		2012		2013		2014	
	%EAR	SPE	%EAR	SPE	%EAR	SPE	%EAR	SPE	%EAR	SPE	%EAR	SPE	%EAR	SPE
Always Limiting Nutrients														
Energy	100%	0.344	100%	0.423	100%	0.344	100%	0.402	100%	0.391	100%	0.213	100%	0.302
Vitamin B12	100%	0.029	100%	0.032	100%	0.029	100%	0.030	100%	0.027	100%	0.027	100%	0.032
Vitamin A	100%	0.467	100%	0.420	100%	0.448	100%	0.407	100%	0.470	100%	0.548	100%	0.500
Vitamin E	100%	0.086	100%	0.109	100%	0.116	100%	0.082	100%	0.049	100%	0.107	100%	0.058
Sometimes Limiting Nutrients														
Calcium	104%	0.074	114%	0.016	107%	0.063	100%	0.079	103%	0.062	100%	0.104	100%	0.109

Note: Data shown are mean fraction of the estimated average requirement for an adult woman of 55kg at an energy level of 2,000 kcal/day consumed each day (%EAR). The mean Shadow Price Elasticity (SPE) of each nutrient when it is limiting. SPE is defined as the percentage change of CoNA if the EAR for that nutrient were increased by 1%. Methods are specified in the text.

Figure 6. CoNA for least-cost diet by limiting nutrients in Ghana, Mar 2009-Dec 2014



Note: Data shown are total cost in each month of the foods needed for lowest cost of nutrient adequacy (CoNA), for an adult woman of 55kg at a dietary energy level of 2,000 kcal/day.

For Tanzania, the CoNA solution to equations (3) – (6) provides 60 diet packages, one for each month from January 2011 to December 2015. As shown in Table 5, a total of 10 food items are ever selected, of which four (dried sardines, spinach, soybeans and white maize) are included in all months. Soybeans, white maize grains and amaranth had the largest mean intakes of 198g, 147g and 135g per day.

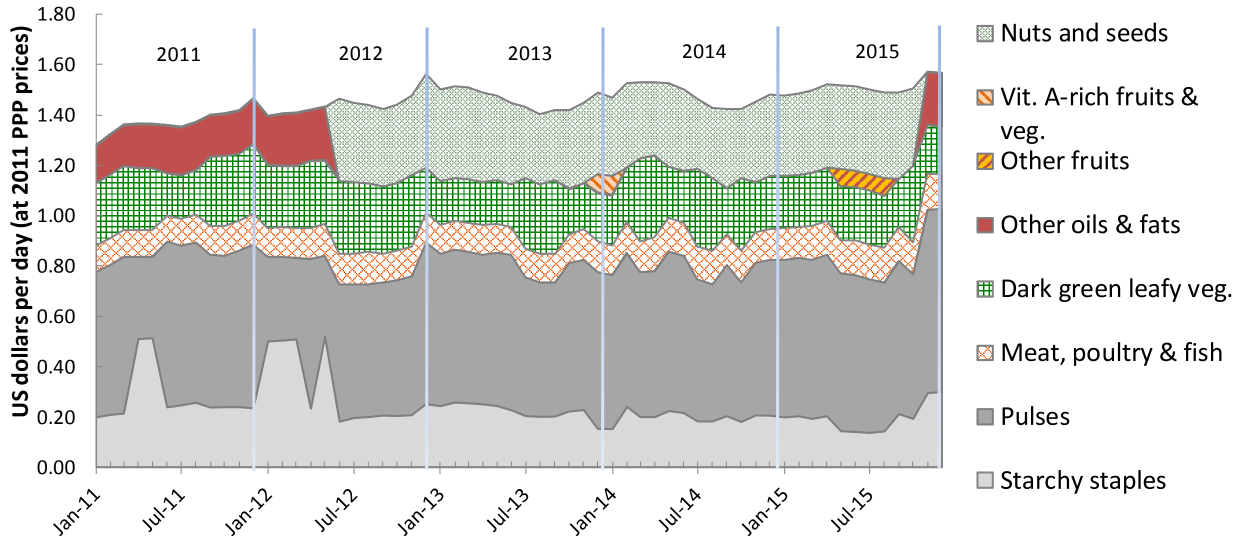
Table 5. Foods consumed to construct CoNA diet plans in Tanzania, Jan 2011-Dec 2015

Food Item	2011-2015		2011		2012		2013		2014		2015	
	Mean	%Selected	Mean	%Selected	Mean	%Selected	Mean	%Selected	Mean	%Selected	Mean	%Selected
Cassava Flour	22	10%	36	17%	73	33%	--	--	--	--	--	--
Cassava Fresh	36	42%	20	25%	7	8%	58	67%	44	50%	49	58%
Cooking Oil Variety[3]	6	32%	18	100%	7	42%	--	--	--	--	3	17%
Dried Sardines	14	100%	14	100%	14	100%	14	100%	14	100%	14	100%
Mchicha (amaranth)	135	100%	150	100%	162	100%	122	100%	133	100%	111	100%
Groundnuts	61	68%	--	--	48	58%	90	100%	88	100%	77	83%
Oranges	3	7%	--	--	--	--	--	--	--	--	14	33%
Papaya	1	3%	--	--	--	--	3	8%	3	8%	--	--
Soya Beans	198	100%	206	100%	169	100%	203	100%	201	100%	210	100%
White Maize Grains	147	100%	196	100%	163	100%	120	100%	132	100%	127	100%

Note: Data shown are mean intake (g/day) and intake frequency (percent of days) for lowest-cost diets that reach the estimated average requirement (EAR) of essential nutrients for an adult woman of 55kg at an energy level of 2,000 kcal/day. Methods are as specified in text. Assuming the average of cottonseed oil and sunflower oil according to price data after 2016 provided by TSS.

The CoNA indicator of Tanzania increased 22.3% from USD 1.28 in January 2011 per day to USD 1.57 in December 2015. In terms of food groups, pulses (soybeans) contribute the most accounting for 39.5% of CoNA, while starchy staples (white maize grains, cassava flour or fresh cassava) and dark green leafy vegetables (amaranth) account for 16.7% and 15.9% respectively. We also found that other fats and oils (cottonseed oil and sunflower oil) and nuts and seeds (natural groundnuts) substituted each other in the selected diet packages, and vitamin A-rich fruits and vegetable (papaya) and other fruits (oranges) compensated dark green leafy vegetables (amaranth) occasionally.

Figure 7. CoNA for least-cost diet by food groups in Tanzania, Jan 2011-Dec 2015



Note: Data shown are total cost in each month of the foods needed for lowest cost of nutrient adequacy (CoNA), for an adult woman of 55kg at a dietary energy level of 2,000 kcal/day.

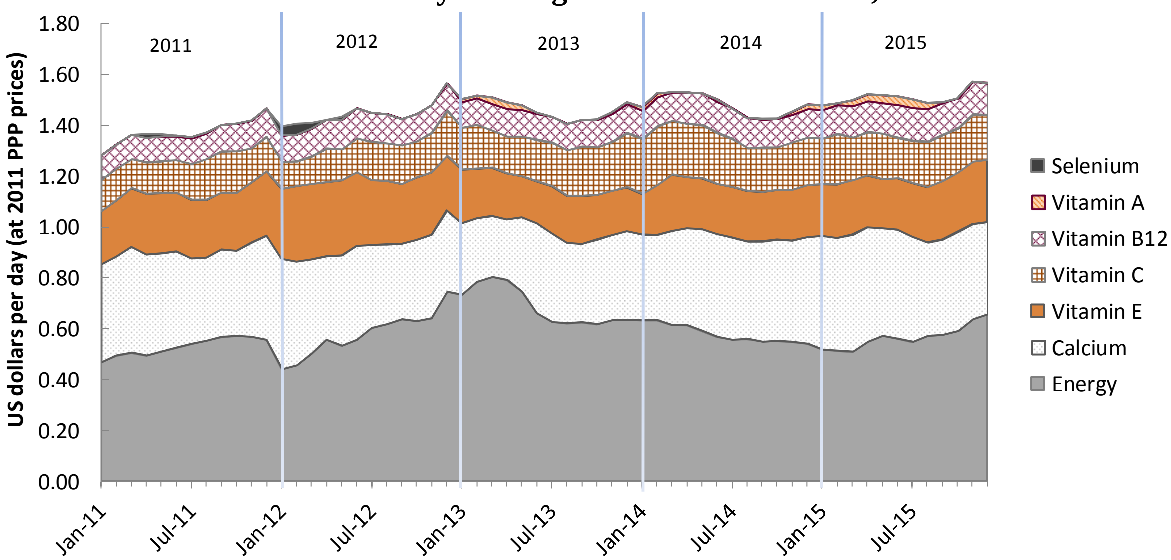
In Tanzania, there were in total of seven limiting nutrients, including the same five limiting nutrients as Ghana plus vitamin C and selenium. Dietary energy, calcium, vitamin C, B12 and E were limiting nutrients in all observations. Using the SPE as a criterion, dietary energy was the most constraining nutritional factor in Tanzania, as a 1% increase in daily dietary energy requirement from 2,000 to 2,020 kcal would increase CoNA by 0.4%. The most constraining individual nutrient was calcium with an average SPE of 0.25, meaning an increase in CoNA of 0.25% if calcium requirements rose from 800mg to 808mg. Unlike in Ghana, vitamin A in Tanzania only occasionally limited CoNA with an SPE of only 0.005. As shown in Figure 8, the nutrients contributing CoNA the most were calcium, followed by vitamin E, C, and B12.

Table 6. Nutrient requirements contributing to CoNA in Tanzania, Jan 2011-Dec 2015

Nutrient	2011-2015		2011		2012		2013		2014		2015	
	%EAR	SPE	%EAR	SPE	%EAR	SPE	%EAR	SPE	%EAR	SPE	%EAR	SPE
Always Limiting Nutrients												
Energy	100%	0.404	100%	0.385	100%	0.398	100%	0.470	100%	0.391	100%	0.375
Calcium	100%	0.251	100%	0.272	100%	0.241	100%	0.208	100%	0.261	100%	0.273
Vitamin C	100%	0.113	100%	0.100	100%	0.093	100%	0.120	100%	0.133	100%	0.117
Vitamin B12	100%	0.076	100%	0.073	100%	0.076	100%	0.071	100%	0.078	100%	0.081
Vitamin E	100%	0.151	100%	0.168	100%	0.185	100%	0.124	100%	0.133	100%	0.144
Sometimes Limiting Nutrients												
Vitamin A	128%	0.005	142%	0.001	153%	0.000	116%	0.007	126%	0.004	105%	0.011
Selenium	142%	0.002	152%	0.002	134%	0.007	140%	--	143%	--	143%	--

Note: Data shown are mean fraction of the estimated average requirement for an adult woman of 55kg at an energy level of 2,000 kcal/day consumed each day (%EAR). The mean Shadow Price Elasticity (SPE) of each nutrient when it is limiting. SPE is defined as the percentage change of CoNA if the EAR for that nutrient were increased by 1%. Methods are as specified in text.

Figure 8. CoNA for least-cost diet by limiting nutrients in Tanzania, Jan 2011-Dec 2015



Note: Data shown are total cost in each month of the foods needed for lowest cost of nutrient adequacy (CoNA), for an adult woman of 55kg at a dietary energy level of 2,000 kcal/day.

Discussion and conclusions

This paper introduces novel price indexes designed to measure the cost of foods that meet international standards for a nutritious diet, rather than the foods actually consumed. In particular, we use a Cost of Diet Diversity (CoDD) index to capture the minimum cost of acquiring at least one food from at least five different food groups as defined by the widely-used Minimum Dietary Diversity for Women (MDD-W) indicator, and compare those results with a Cost of Nutrient Adequacy (CoNA) measure based on foods needed to meet estimated average requirements of essential nutrients and dietary energy.

Using national average monthly market price data for Ghana from 2009 through 2014, we find that the cost of meeting the diet diversity standard fluctuates seasonally and since mid-2010 has risen about 10 percent per year faster than inflation due to rising relative prices for fruit and fish, while the cost of nutrient adequacy rose even faster due primarily to increased cost of foods rich in vitamin A and calcium. Similar data for Tanzania from 2011 through 2015 show small increases in 2011 and 2012 but stable prices thereafter. In both Ghana and Tanzania, the relative of starchy staples, grains and pulses remained relatively stable, contributing to food security and the affordability of dietary energy. Differences in the cost of nutritious diets are due to variation in relative affordability of other food groups, notably vitamin A rich or other fruits and vegetables.

The CoDD and CoNA indexes are intended to track access and affordability of foods required for a given nutritional standard, which may be very different from what is actually consumed. CoDD is a unit-free measure of changes in cost, while CoNA is a cost per day which we find to be roughly on the order of $1.50 per person per day. That compares to estimated national average per-capita food expenditure in rural areas in 2012 of 2.99 in Ghana and 1.73 in Tanzania, ranging by region within each country from 1.77 to 3.65 in Ghana and from 1.40 to 2.06 in Tanzania (*IFPRI 2017*). CoNA is particularly useful for identifying limiting nutrients, notably the high and rising cost of acquiring vitamin A in Ghana relative to Tanzania.

The empirical results presented here are limited to the foods included in each specific price monitoring system. The market information data collected in Ghana over this period omitted two nutritionally important food groups entirely, dark green leafy vegetables and dairy; MoFA has already begun to collect a much larger range of prices so as to track access to more nutritious foods in the future (Nortey 2017). Furthermore, each type of food is represented by only a few items, and those might not always correspond to the least-cost source of each food group for CoDD or each nutrient for CoNA. Also the prices used here are national averages, and limited market integration ensures that relative prices vary by location. By design, the Ghana data from MoFA represent a wider range of rural markets than the Tanzania data. Future work will focus on regional differences in these prices, as influenced by local supply-demand conditions and infrastructure for trade between locations, and the consequence of resulting price differences for food choice and nutritional outcomes.

Empirical results are driven not only by prices, but by the indicator used to define a nutritious diet. Our novel index for the cost of dietary diversity corresponds to meeting the MDD-W criterion, for use in settings where data reveal whether or not an item from each specified food group is consumed, but not its quantity or nutrient composition. This extends standard metrics that use diet diversity without reference to nutritional function as in Clements and Si (2017), or a fixed basket of food quantities such as the U.S. Healthy Eating Index used by Beatty, Lin and Smith (2014) for the United States. Future work could develop price indexes around the wide range of recommended diets proposed in healthy-eating guidelines and diet quality measures (Marshall, Burrows and Collins 2014). Numerous studies have tracked changes in the cost of meeting specific dietary guidelines, such as Jones et al. (2014) for the UK or Lewis and Lee (2016) in Australia, and future work could construct internationally-comparable indexes for the cost of recommended diets in Africa and other low-income settings. By analogy to the CoDD and CoNA terminology used here, such indexes could be called the Cost of Recommended Diets (CoRD).

Another type of price index for the cost of nutritious diets could be designed around traditional CPI data, weighting each item’s contribution to health using a monotonic scoring system such as NuVal (Katz et al. 2010) or other nutrient profiling algorithms reviewed by Drewnowski (2017). Those weights would be larger for more beneficial foods that are associated with lower future disease risk, and could be made negative for foods like sugar-sweetened beverages and salty snacks that are associated with diet-related diseases such as diabetes and hypertension. Such an index would be designed to capture non-market costs as well as benefits for future health of consuming each food, in the form of a nutritionally-weighted consumer price index (nCPI).

In summary, the index proposed here for the cost of diet diversity, alongside traditional measures for the cost of nutrient adequacy, allow us to measure changes in the (un)affordability of healthier diets than those currently consumed. Doing so offers the potential to measure the degree to which policy and program interventions improve access to nutritious diets at each time and place. Future improvements to tracking nutritious food prices will require high quality representation of diverse low-cost food sources for diet diversity, focusing on nutrient-rich foods that are important to dietary intakes, and regionally representative price data to ensure that results are representative. With more diverse and more locally representative data, this method can be used to track the cost of nutritious diets across seasons as a way of characterizing local food environments.

Annex of Supplemental Information

Table A1. Descriptive Statistics of Monthly Food Prices per kg – Ghana (2011$)

Food Groups	No	Foodstuffs	Obs.	Mean	Std. Dev.	CV	Min	Max
Grains, white roots and tubers, and plantains	1	Cassava	70	0.53	0.11	0.20	0.36	0.76
	2	Cocoyam	70	1.19	0.27	0.23	0.79	1.82
	3	Kokonte	70	1.27	0.21	0.17	0.90	1.81
	4	Gari	70	1.47	0.25	0.17	1.15	2.41
	5	Imported Rice	70	2.68	0.42	0.16	2.19	3.98
	6	Local Rice	70	1.86	0.22	0.12	1.51	2.67
	7	Maize	70	0.95	0.17	0.18	0.69	1.44
	8	Millet	70	1.48	0.19	0.13	1.16	1.94
	9	Paddy Rice	56	1.27	0.40	0.32	0.76	2.73
	10	Plantains	70	1.79	0.60	0.33	1.11	4.12
	11	Sorghum	70	1.20	0.13	0.11	0.97	1.53
	12	Yam	70	1.23	0.20	0.16	0.90	1.75
Pulses	13	Cowpea	70	2.06	0.35	0.17	1.45	2.84
	14	Soya Beans	70	1.30	0.31	0.24	0.57	2.11
Nuts & seeds	15	Groundnut	70	3.26	0.62	0.19	2.25	4.45
Meat, poultry and fish	16	Anchovies	70	6.33	1.37	0.22	3.19	11.68
	17	Salted Dried Tilapia Fish	70	2.43	0.58	0.24	0.99	4.15
	18	Smoked Herrings	70	3.15	0.70	0.22	2.01	5.45
Eggs	19	Eggs	70	8.90	0.63	0.07	7.47	10.84
Vitamin A-rich vegetables and fruits	20	Mangoes	70	0.85	0.31	0.36	0.38	1.76
	21	Tomatoes	70	3.74	1.24	0.33	1.82	7.18
Other vegetables	22	Garden Eggs	70	2.29	0.59	0.26	1.20	4.14
	23	Large Onions	70	3.58	1.16	0.32	1.68	5.81
Other fruits	24	Bananas	70	1.69	0.33	0.20	1.02	2.53
	25	Oranges	70	1.35	0.41	0.31	0.55	3.09
	26	Pineapples	70	1.47	0.16	0.11	1.15	1.94

Note: Authors' calculations, from Ghana Ministry of Food and Agriculture data. Two food groups in the MDD-W are not represented in this dataset: Dairy, and Dark Green Leafy Vegetables. Kokonte and Gari refer to processed cassava products. Groundnut refers to shelled groundnut, with prices for unshelled groundnut omitted from data analysis.

Table A2. Descriptive Statistics of Monthly Food Prices per kg – Tanzania (2011$)

Food Group	No	Foodstuff	Obs.	Mean	Std. Dev.	CV	Min	Max
Grains, white roots and tubers, and plantains	1	Cassava flour	60	2.00	0.23	0.11	1.62	2.63
	2	Cassava fresh	60	1.23	0.11	0.09	0.95	1.43
	3	Cooking Bananas Green	60	2.00	0.11	0.05	1.77	2.32
	4	Finger millet	60	2.55	0.43	0.17	1.89	3.30
	5	Maize Flour	60	1.69	0.20	0.12	1.32	2.28
	6	Potatoes – round	60	1.73	0.10	0.06	1.52	2.02
	7	Rice	60	2.68	0.42	0.16	2.07	3.53
	8	Sweet Potatoes	60	1.47	0.12	0.08	1.25	1.69
	9	Wheat Flour	60	2.24	0.14	0.06	2.03	2.57
	10	White Maize	60	1.11	0.13	0.12	0.89	1.49
Pulses	11	Beans (soya)	60	2.90	0.11	0.04	2.65	3.10
	12	Lentils	60	3.81	0.35	0.09	3.20	4.40
	13	Red dry beans	60	2.63	0.13	0.05	2.43	2.94
Nuts & seeds	14	Natural Groundnuts	60	3.72	0.31	0.08	3.28	4.44
Dairy	15	Fresh cow milk	60	1.76	0.10	0.05	1.45	1.87
	16	Powdered milk	60	39.56	1.86	0.05	34.77	43.18
Meat, poultry and fish	17	Beef sausage	60	17.48	0.34	0.02	16.95	18.37
	18	Beef with bones	60	10.89	0.52	0.05	9.65	12.32
	19	Beef without bones	60	10.89	0.40	0.04	9.87	12.30
	20	Dried sardines	60	8.99	0.70	0.08	7.68	10.37
	21	Goat meat	60	10.37	0.41	0.04	9.12	11.10
	22	Industrially bred live chicken	60	13.99	0.67	0.05	11.92	14.88
	23	Pork meat	60	11.93	1.04	0.09	9.22	13.63
	24	Traditionally bred live chicken	60	25.34	1.69	0.07	21.16	28.23
Eggs	25	Eggs-layers	60	12.05	0.41	0.03	11.28	12.70
	26	Eggs-traditional	60	16.89	0.99	0.06	14.73	18.11
Dark green leafy vegetables	27	Mchicha (spinach)	60	1.72	0.17	0.10	1.46	2.05
Vitamin A-rich vegetables and fruits	28	Carrots	60	2.89	0.28	0.10	2.46	3.72
	29	Mangoes	60	2.67	0.38	0.14	1.78	3.64
	30	Papaya	60	2.42	0.22	0.09	2.03	2.86
	31	Tomatoes red	60	1.88	0.21	0.11	1.50	2.44

Table A2 (continued)

Food Group	No	Foodstuff	Obs.	Mean	Std. Dev.	CV	Min	Max
Other vegetables	32	Bitter tomatoes	60	2.22	0.12	0.05	1.96	2.68
	33	Egg plant	60	2.36	0.12	0.05	2.12	2.71
	34	Cabbages	60	1.15	0.11	0.10	0.94	1.43
	35	Green peas	60	20.07	1.41	0.07	16.78	23.01
	36	Green bell pepper	60	3.29	0.18	0.06	2.96	3.83
	37	Ladies finger (okra)	60	3.72	0.25	0.07	3.29	4.37
	38	Onions	60	2.57	0.31	0.12	2.08	3.54
Other fruits	39	Apples (Imported)	60	10.18	0.84	0.08	8.24	12.28
	40	Avocado	60	3.05	0.19	0.06	2.67	3.49
	41	Coconut mature	60	8.94	0.83	0.09	7.75	11.10
	42	Lemons	60	3.41	0.59	0.17	2.39	5.22
	43	Limes	60	4.69	0.86	0.18	3.60	7.07
	44	Oranges	60	2.04	0.21	0.10	1.60	2.59
	45	Pineapples	60	3.33	0.33	0.10	2.77	3.99
	46	Sweet banana	60	2.98	0.25	0.08	2.41	3.48

Note: Authors’ calculations, from Tanzania Bureau of Statistics data.

Figure A1. Minimum Prices by Foodstuffs and the CoDD1/CoDD2 Indices in Ghana (per kg)

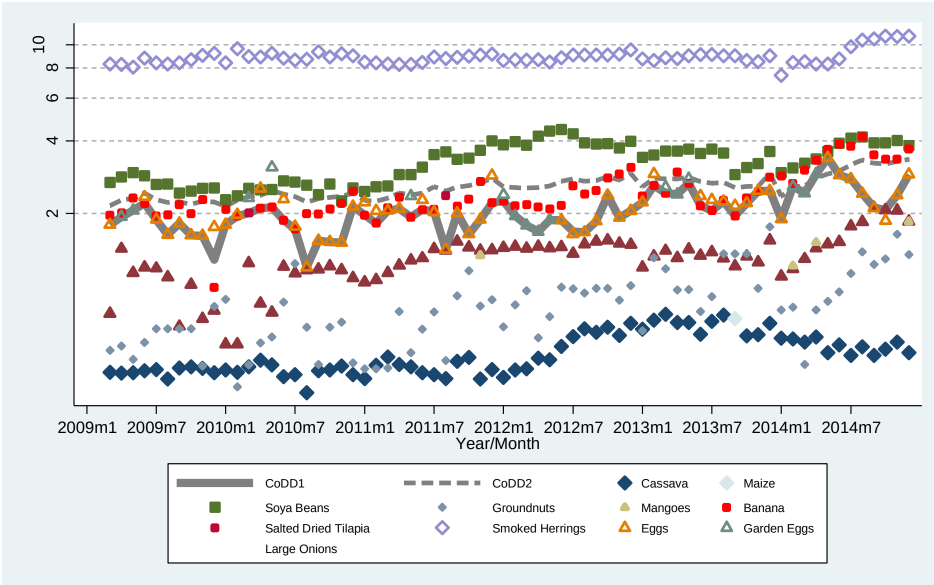


Figure A2. Minimum Costs by Foodstuffs and the CoDD1/CoDD2 Indices in Tanzania (per kg)

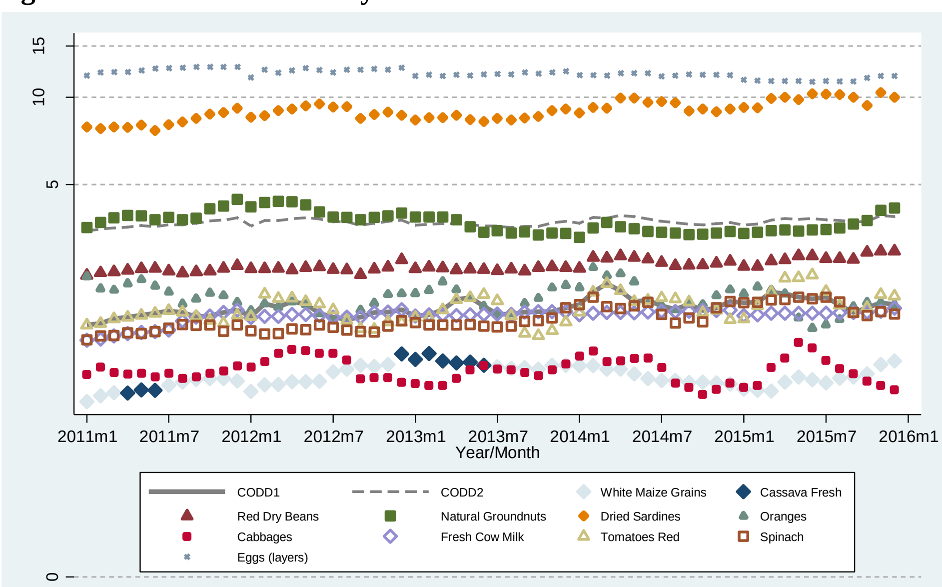
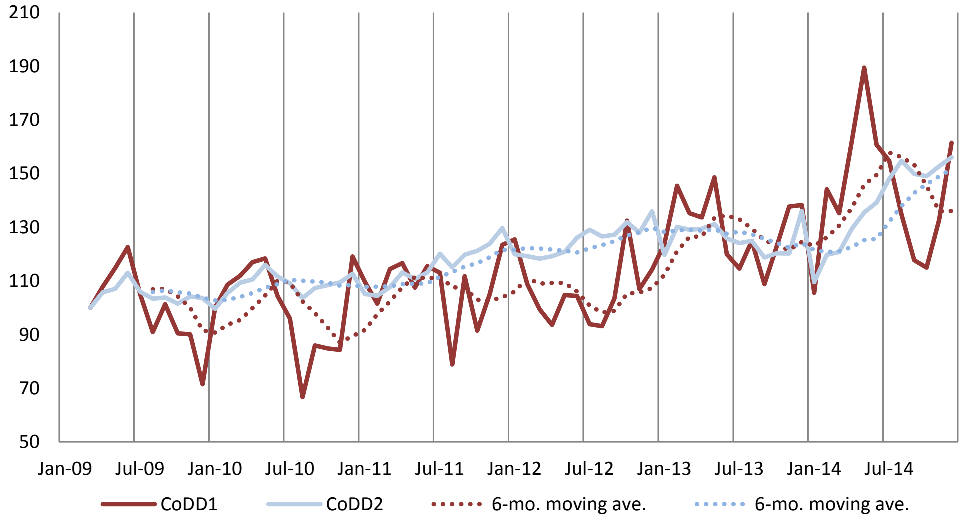
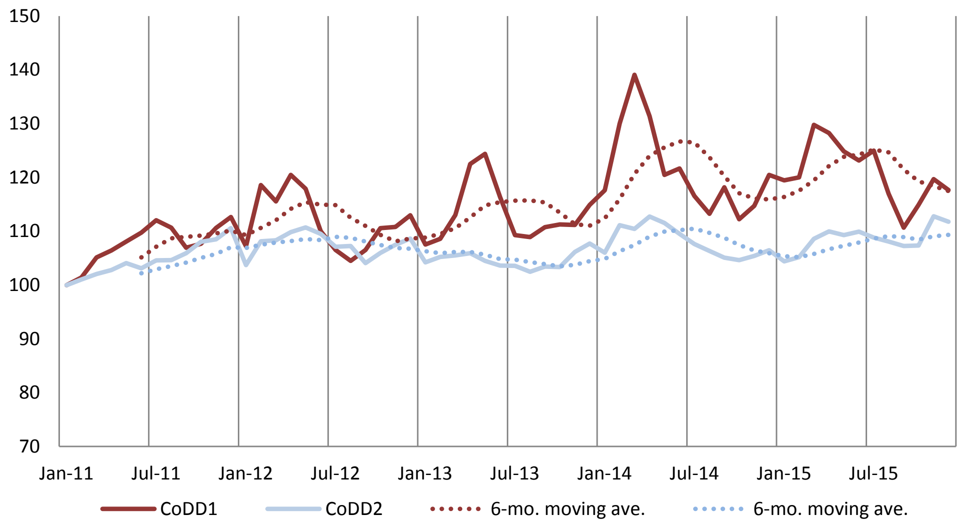


Figure A3. CoDD1 and CoDD2 Indices in Ghana (per kg)



Note: Base period price of the indexes is the CoDD value of March 2009. Data imputation for Soya Beans and Mangoes.

Figure A4. CoDD1 and CoDD2 Indices in Tanzania (per kg) [1]



Note: Base period price of the indexes is the CoDD value of January 2011.

Table A3. Nutritional and Dietary Energy Criteria

No	Nutrient Groups	Nutrients	EARs [1]	Units
1	**Dietary Energy**	Energy	2,000	kcal/day
2	**Macronutrient**	Protein [2]	36.3	g/day
3	**Minerals**	Calcium	800	mg/day
4		Iron	8.1	mg/day
5		Magnesium	255	mg/day
6		Phosphorus	580	mg/day
7		Zinc	6.8	mg/day
8		Copper	0.7	mcg/day
9		Selenium	45	mcg/day
10	**Vitamins**	Vitamin C	60	mg/day
11		Thiamin	0.9	mg/day
12		Riboflavin	0.9	mg/day
13		Niacin	11	mg/day
14		Vitamin B6	1.1	mg/day
15		Folate	320	mg/day
16		Vitamin B12	2	mcg/day
17		Vitamin A	500	mcg/day
18		Vitamin E	12	mg/day

Note: Data shown are estimated Average Requirement (EAR) for adult women from 19 to 30 years old, from Dietary Reference Intakes (DRIs) developed by the U.S. Institute of Medicine of the National Academies. EAR of protein is calculated based on an adult woman of 55kg at a dietary energy level of 2000 kcal/day.

Table A4. Food Items, Food Groups and Food Composition (Ghana)

Foods	Food Groups	Energy	Protein	Calcium	Iron	Magnesium	Phosphorus	Zinc	Vitamin C	Thiamin	Riboflavin	Niacin	Vitamin B6	Folate	Vitamin B12	Vitamin A	Vitamin E	Copper	Selenium
ANCHOVIES	Meat, poultry and fish	1.310	0.204	1.470	0.033	0.410	1.740	0.017	0.000	0.001	0.003	0.140	0.001	0.090	0.006	0.150	0.006	0.002	0.365
BANANA	Other fruits	0.890	0.011	0.050	0.003	0.270	0.220	0.002	0.087	0.000	0.001	0.007	0.004	0.200	0.000	0.030	0.001	0.001	0.010
CASSAVA	Grains, white roots and tubers, and plantains	1.600	0.014	0.160	0.003	0.210	0.270	0.003	0.206	0.001	0.000	0.009	0.001	0.270	0.000	0.010	0.002	0.001	0.007
COCONUT OIL	Other oils and fats	8.920	0.000	0.010	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000
COCOYAM	Grains, white roots and tubers, and plantains	1.120	0.015	0.430	0.006	0.330	0.840	0.002	0.045	0.001	0.000	0.006	0.003	0.220	0.000	0.040	0.024	0.002	0.007
COWPEA	Pulses	3.360	0.235	1.100	0.083	1.840	4.240	0.034	0.015	0.009	0.002	0.021	0.004	6.330	0.000	0.030	0.004	0.008	0.090
DRIED CASSAVA CHIPS (KOKONTE)	Grains, white roots and tubers, and plantains	3.350	0.019	1.380	0.015	0.450	1.020	0.007	0.040	0.001	0.001	0.012	0.002	0.470	0.000	0.000	0.004	0.002	0.000
EGGS	Eggs	1.430	0.126	0.560	0.018	0.120	1.980	0.013	0.000	0.000	0.005	0.001	0.002	0.470	0.009	1.600	0.011	0.001	0.307
GARDEN EGGS	Other vegetables	0.250	0.010	0.090	0.002	0.140	0.240	0.002	0.022	0.000	0.000	0.006	0.001	0.220	0.000	0.010	0.003	0.001	0.003
GARI	Grains, white roots and tubers, and plantains	3.350	0.019	1.380	0.015	0.450	1.020	0.007	0.040	0.001	0.001	0.012	0.002	0.470	0.000	0.000	0.004	0.002	0.000
GROUNDNUT	Nuts and seeds	5.670	0.258	0.920	0.046	1.680	3.760	0.033	0.000	0.006	0.001	0.121	0.003	2.400	0.000	0.000	0.083	0.011	0.072
GROUNDNUT OIL	Other oils and fats	8.840	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.157	0.000	0.000
IMPORTED RICE	Grains, white roots and tubers, and plantains	3.650	0.071	0.280	0.008	0.250	1.150	0.011	0.000	0.001	0.000	0.016	0.002	0.080	0.000	0.000	0.001	0.002	0.151
LARGE ONIONS	Other vegetables	0.400	0.011	0.230	0.002	0.100	0.290	0.002	0.074	0.000	0.000	0.001	0.001	0.190	0.000	0.000	0.000	0.000	0.005
LOCAL RICE	Grains, white roots and tubers, and plantains	3.580	0.065	0.030	0.008	0.230	0.950	0.011	0.000	0.001	0.000	0.016	0.002	0.060	0.000	0.000	0.000	0.002	0.000
MAIZE	Grains, white roots and tubers, and plantains	3.650	0.094	0.070	0.027	1.270	2.100	0.022	0.000	0.004	0.002	0.036	0.006	0.190	0.000	0.110	0.005	0.003	0.155
MANGOES	Vitamin A-rich vegetables and fruits	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MILLET	Grains, white roots and tubers, and plantains	3.780	0.110	0.080	0.030	1.140	2.850	0.017	0.000	0.004	0.003	0.047	0.004	0.850	0.000	0.000	0.001	0.008	0.027
ORANGES	Other fruits	0.460	0.007	0.430	0.001	0.100	0.120	0.001	0.450	0.001	0.000	0.004	0.001	0.170	0.000	0.110	0.002	0.000	0.005
PADDY RICE	Grains, white roots and tubers, and plantains	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
PALM OIL	Other oils and fats	8.840	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.159	0.000	0.000

Table A4 (continued)

Foods	Food Groups	Energy	Protein	Calcium	Iron	Magnesium	Phosphorus	Zinc	Vitamin C	Thiamin	Riboflavin	Niacin	Vitamin B6	Folate	Vitamin B12	Vitamin A	Vitamin E	Copper	Selenium
PINEAPPLE	Other fruits	0.500	0.005	0.130	0.003	0.120	0.080	0.001	0.478	0.001	0.000	0.005	0.001	0.180	0.000	0.030	0.000	0.001	0.001
PLANTAIN	Grains, white roots and tubers, and plantains	1.220	0.013	0.030	0.006	0.370	0.340	0.001	0.184	0.001	0.001	0.007	0.003	0.220	0.000	0.560	0.001	0.001	0.015
SALTED DRIED TILAPIA FISH	Meat, poultry and fish	0.960	0.201	0.100	0.006	0.270	1.700	0.003	0.000	0.000	0.001	0.039	0.002	0.240	0.016	0.000	0.004	0.001	0.418
SMOKED HERRINGS	Meat, poultry and fish	1.580	0.180	0.570	0.011	0.320	2.360	0.010	0.007	0.001	0.002	0.032	0.003	0.100	0.137	0.280	0.011	0.001	0.365
SORGHUM	Grains, white roots and tubers, and plantains	3.290	0.106	0.130	0.034	1.650	2.890	0.017	0.000	0.003	0.001	0.037	0.004	0.200	0.000	0.000	0.005	0.003	0.122
SOYA BEANS	Pulses	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TOMATOES	Vitamin A-rich vegetables and fruits	0.180	0.009	0.100	0.003	0.110	0.240	0.002	0.137	0.000	0.000	0.006	0.001	0.150	0.000	0.420	0.005	0.001	0.000
YAM	Grains, white roots and tubers, and plantains	1.180	0.015	0.170	0.005	0.210	0.550	0.002	0.171	0.001	0.000	0.006	0.003	0.230	0.000	0.070	0.004	0.002	0.007

Note: Food groups apply the definition of MDD-W. Food composition data sources include National Nutrient Database for Standard Reference (USDA) and FAO's West African Food Composition Table. Data shown are nutrients contents per gram of food items. Unit is kcal for dietary energy, g for protein, mg for calcium, iron, magnesium, phosphorus, zinc, vitamin C, thiamin, riboflavin, niacin, vitamin B6, Folate, and vitamin E, and mcg for vitamin B12, vitamin A, Copper and Selenium.

Table A5. Food Items, Food Groups and Food Compositions (Tanzania)

Foods	Food Groups	Energy	Protein	Calcium	Iron	Magnesium	Phosphorus	Zinc	Vitamin C	Thiamin	Riboflavin	Niacin	Vitamin B6	Folate	Vitamin B12	Vitamin A	Vitamin E	Copper	Selenium
APPLES (IMPORTED)	Other fruits	0.520	0.003	0.060	0.001	0.050	0.110	0.000	0.046	0.000	0.000	0.001	0.000	0.030	0.000	0.030	0.002	0.000	0.000
AVOCADO	Other fruits	1.600	0.020	0.120	0.006	0.290	0.520	0.006	0.100	0.001	0.001	0.017	0.003	0.810	0.000	0.070	0.021	0.002	0.004
BEANS (SOYA - BLANKETI)	Pulses	4.460	0.365	2.770	0.157	2.800	7.040	0.049	0.060	0.009	0.009	0.016	0.004	3.750	0.000	0.010	0.009	0.017	0.178
BEEF SAUSAGE	Meat, poultry and fish	4.050	0.155	0.150	0.015	0.130	1.850	0.029	0.007	0.000	0.001	0.032	0.002	0.050	0.020	0.250	0.005	0.001	0.000
BEEF WITHOUT BONES (STEAK)	Meat, poultry and fish	2.780	0.175	0.080	0.019	0.170	1.560	0.036	0.000	0.001	0.002	0.035	0.003	0.070	0.027	0.000	0.000	0.001	0.159
BITTER TOMATOES (NYANYA CHUNGU)	Other vegetables	0.250	0.010	0.090	0.002	0.140	0.240	0.002	0.022	0.000	0.000	0.006	0.001	0.220	0.000	0.010	0.003	0.001	0.003
BRINJALS/EGG PLANT (BILINGANYA)	Other vegetables	0.250	0.010	0.090	0.002	0.140	0.240	0.002	0.022	0.000	0.000	0.006	0.001	0.220	0.000	0.010	0.003	0.001	0.003
CABBAGES	Other vegetables	0.410	0.009	0.330	0.003	0.120	0.350	0.002	0.059	0.001	0.001	0.010	0.001	0.190	0.000	8.350	0.007	0.000	0.001
CARROTS	Vitamin A-rich vegetables and fruits	0.410	0.009	0.330	0.003	0.120	0.350	0.002	0.059	0.001	0.001	0.010	0.001	0.190	0.000	8.350	0.007	0.000	0.001
CASSAVA FLOUR	Grains, white roots and tubers, and plantains	3.350	0.019	1.380	0.015	0.450	1.020	0.007	0.040	0.001	0.001	0.012	0.002	0.470	0.000	0.000	0.004	0.002	0.000
CASSAVA FRESH	Grains, white roots and tubers, and plantains	1.600	0.014	0.160	0.003	0.210	0.270	0.003	0.206	0.001	0.000	0.009	0.001	0.270	0.000	0.010	0.002	0.001	0.007
COCONUT MATURE (ISIYOVUNJWA)	Other fruits	1.620	0.016	0.190	0.022	0.170	1.110	0.004	0.020	0.001	0.001	0.006	0.000	0.120	0.000	0.000	0.003	0.002	0.000
COOKING BANANA GREEN	Grains, white roots and tubers, and plantains	1.220	0.013	0.030	0.006	0.370	0.340	0.001	0.184	0.001	0.001	0.007	0.003	0.220	0.000	0.560	0.001	0.001	0.015
COOKING FAT	Other oils and fats	7.170	0.009	0.240	0.000	0.020	0.240	0.001	0.000	0.000	0.000	0.000	0.000	0.030	0.002	6.840	0.023	0.000	0.010
COOKING OIL VARIETY	Other oils and fats	8.840	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.382	0.000	0.000
DRIED SARDINES (DAGAA)	Meat, poultry and fish	1.500	0.280	1.030	0.023	0.460	3.670	0.023	0.000	0.000	0.002	0.109	0.013	0.050	0.143	0.250	0.011	0.001	0.000
FINGER MILLET GRAINS (PUNJE ZA ULEZI)	Grains, white roots and tubers, and plantains	3.780	0.110	0.080	0.030	1.140	2.850	0.017	0.000	0.004	0.003	0.047	0.004	0.850	0.000	0.000	0.001	0.008	0.027
FRESH COW MILK	Dairy	0.610	0.032	1.130	0.000	0.100	0.840	0.004	0.000	0.000	0.002	0.001	0.000	0.050	0.005	0.460	0.001	0.000	0.037
GOAT MEAT	Meat, poultry and fish	1.090	0.206	0.130	0.028	0.000	1.800	0.040	0.000	0.001	0.005	0.038	0.000	0.050	0.011	0.000	0.000	0.003	0.088

Table A5 (continued)

Foods	Food Groups	Energy	Protein	Calcium	Iron	Magnesium	Phosphorus	Zinc	Vitamin C	Thiamin	Riboflavin	Niacin	Vitamin B6	Folate	Vitamin B12	Vitamin A	Vitamin E	Copper	Selenium
GREEN PEAS (NJEGERE - ZILIZOMENYWA)	Pulses	0.420	0.028	0.430	0.021	0.240	0.530	0.003	0.600	0.002	0.001	0.006	0.002	0.420	0.000	0.540	0.004	0.001	0.007
GREEN PEPPER (HOHO)	Other vegetables	0.200	0.009	0.100	0.003	0.100	0.200	0.001	0.804	0.001	0.000	0.005	0.002	0.100	0.000	0.180	0.004	0.001	0.000
INDUSTRIALLY BRED LIVE CHICKEN - (BROILERS)	Meat, poultry and fish	2.130	0.183	0.110	0.013	0.200	1.490	0.015	0.026	0.001	0.002	0.066	0.003	0.300	0.011	2.320	0.000	0.001	0.118
LADIES FINGER/OKRA (BAMIA)	Other vegetables	0.330	0.019	0.820	0.006	0.570	0.610	0.006	0.230	0.002	0.001	0.010	0.002	0.600	0.000	0.360	0.003	0.001	0.007
LEMONS	Other fruits	0.290	0.011	0.260	0.006	0.080	0.160	0.001	0.530	0.000	0.000	0.001	0.001	0.110	0.000	0.010	0.002	0.000	0.004
LENTILS (CHOROKO)	Pulses	2.970	0.254	0.610	0.070	1.030	3.910	0.039	0.000	0.006	0.002	0.023	0.007	2.950	0.000	0.030	0.005	0.007	0.000
LIMES	Other fruits	0.300	0.007	0.330	0.006	0.060	0.180	0.001	0.291	0.000	0.000	0.002	0.000	0.080	0.000	0.020	0.002	0.001	0.004
MAIZE FLOUR (WHITE)	Grains, white roots and tubers, and plantains	3.610	0.069	0.070	0.024	0.930	2.720	0.017	0.000	0.002	0.001	0.019	0.004	0.250	0.000	0.000	0.004	0.002	0.154
MANGOES	Vitamin A-rich fruits and vegetables	0.600	0.008	0.110	0.002	0.100	0.140	0.001	0.364	0.000	0.000	0.007	0.001	0.430	0.000	0.540	0.009	0.001	0.006
MARGARINE	Other oils and fats	7.190	0.009	0.300	0.000	0.030	0.230	0.000	0.002	0.000	0.000	0.000	0.000	0.010	0.001	8.190	0.031	0.000	0.000
MCHICHA (SPINACH)	Dark green leafy vegetables	0.230	0.029	0.990	0.027	0.790	0.490	0.005	0.281	0.001	0.002	0.007	0.002	1.940	0.000	4.690	0.020	0.001	0.010
NATURAL GROUNDNUTS (UN ROASTED)	Nuts and seeds	5.670	0.258	0.920	0.046	1.680	3.760	0.033	0.000	0.006	0.001	0.121	0.003	2.400	0.000	0.000	0.083	0.011	0.072
ONE EGG LAYERS	Eggs	1.430	0.126	0.560	0.018	0.120	1.980	0.013	0.000	0.000	0.005	0.001	0.002	0.470	0.009	1.600	0.011	0.001	0.307
ONE EGG TRADITIONAL	Eggs	1.430	0.126	0.560	0.018	0.120	1.980	0.013	0.000	0.000	0.005	0.001	0.002	0.470	0.009	1.600	0.011	0.001	0.307
ORANGES	Other fruits	0.460	0.007	0.430	0.001	0.100	0.120	0.001	0.450	0.001	0.000	0.004	0.001	0.170	0.000	0.110	0.002	0.000	0.005
PAPAYA – PAWPAW	Vitamin A-rich fruits and vegetables	0.430	0.005	0.200	0.003	0.210	0.100	0.001	0.609	0.000	0.000	0.004	0.000	0.370	0.000	0.470	0.003	0.000	0.006
PINEAPPLES	Other fruits	0.500	0.005	0.130	0.003	0.120	0.080	0.001	0.478	0.001	0.000	0.005	0.001	0.180	0.000	0.030	0.000	0.001	0.001
PORK MEAT	Meat, poultry and fish	3.760	0.139	0.190	0.007	0.130	1.550	0.016	0.004	0.006	0.002	0.038	0.003	0.040	0.006	0.020	0.003	0.001	0.284
POTATOES - ROUND/IRISH	Grains, white roots and tubers, and plantains	0.770	0.021	0.120	0.008	0.230	0.570	0.003	0.197	0.001	0.000	0.011	0.003	0.150	0.000	0.000	0.000	0.001	0.004
POWDERED MILK	Dairy	4.950	0.259	9.680	0.007	0.910	7.350	0.035	0.113	0.003	0.013	0.007	0.003	0.390	0.033	2.280	0.005	0.001	0.000
RED DRY BEANS	Pulses	3.370	0.225	0.830	0.067	1.380	4.060	0.028	0.045	0.006	0.002	0.021	0.004	3.940	0.000	0.000	0.002	0.007	0.032

Table A5 (continued)

Foods	Food Groups	Energy	Protein	Calcium	Iron	Magnesium	Phosphorus	Zinc	Vitamin C	Thiamin	Riboflavin	Niacin	Vitamin B6	Folate	Vitamin B12	Vitamin A	Vitamin E	Copper	Selenium
RICE	Grains, white roots and tubers, and plantains	3.600	0.066	0.090	0.008	0.350	1.080	0.012	0.000	0.001	0.000	0.016	0.001	0.090	0.000	0.000	0.000	0.001	0.000
ROUND ONIONS	Other vegetables	0.400	0.011	0.230	0.002	0.100	0.290	0.002	0.074	0.000	0.000	0.001	0.001	0.190	0.000	0.000	0.000	0.000	0.005
SWEET POTATOES	Grains, white roots and tubers, and plantains	0.860	0.016	0.300	0.006	0.250	0.470	0.003	0.024	0.001	0.001	0.006	0.002	0.110	0.000	7.090	0.003	0.002	0.006
SWEET BANANA	Other fruits	0.890	0.011	0.050	0.003	0.270	0.220	0.002	0.087	0.000	0.001	0.007	0.004	0.200	0.000	0.030	0.001	0.001	0.010
TOMATOES RED	Vitamin A-rich vegetables and fruits	0.180	0.009	0.100	0.003	0.110	0.240	0.002	0.137	0.000	0.000	0.006	0.001	0.150	0.000	0.420	0.005	0.001	0.000
TRADITIONALLY BRED LIVE CHICKEN (KUKU WA KIENYEJI)	Meat, poultry and fish	2.130	0.183	0.110	0.013	0.200	1.490	0.015	0.026	0.001	0.002	0.066	0.003	0.300	0.011	2.320	0.000	0.001	0.118
WHEAT FLOUR	Grains, white roots and tubers, and plantains	3.640	0.103	0.150	0.012	0.220	1.080	0.007	0.000	0.001	0.000	0.013	0.000	0.260	0.000	0.000	0.001	0.001	0.339
WHITE MAIZE GRAINS	Grains, white roots and tubers, and plantains	3.650	0.094	0.070	0.027	1.270	2.100	0.022	0.000	0.004	0.002	0.036	0.006	0.000	0.000	0.000	0.000	0.003	0.155

Note: Food groups apply the definition of MDD-W. Food composition data sources include National Nutrient Database for Standard Reference (USDA) and FAO's West African Food Composition Table. Data shown are nutrients contents per gram of food items. Unit is kcal for dietary energy, g for protein, mg for calcium, iron, magnesium, phosphorus, zinc, vitamin C, thiamin, riboflavin, niacin, vitamin B6, Folate, and vitamin E, and mcg for vitamin B12, vitamin A, Copper and Selenium.

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