Market prices and the cost of nutritious diets:

New price indexes to measure food system change

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Advancing Research on Nutrition and Agriculture (ARENA)
pre-conference workshop at ICAE, 28 July 2018

Tufts UNIVERSITY

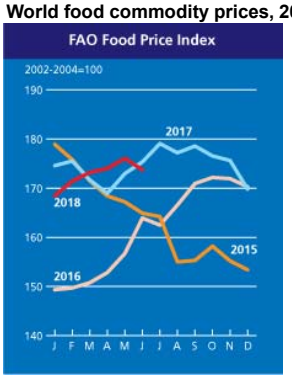
UKaid from the British people

With rapid change in food environments, is the overall cost of nutritious diets easier to buy, or further out of reach?

Photo: Anna Herforth, at Nsawam market, Ghana

Existing food price indexes are weighted by market value and say little about nutrition

World food commodity prices, 2015-2018



Source: www.fao.org/worldfoodsituation, 21 July 2018

For global commodity prices, the FAO Food Price Index consists of five commodity group price indices, weighted with average export shares of each of the groups for 2002-2004.

Total of 23 commodities (73 prices), in 5 groups:

- **Cereals**
  -- wheat (11), maize (1), rice (16)
- **Oils/Fats**
  -- soybean, sunflower, rapeseed, groundnut, cottonseed, copra, palm kernel, palm, linseed, castor (1 each)
- **Dairy**
  -- whole milk powder, skim milk powder, cheese (2 each), cheese (1)
- **Meat**
  -- poultry (13), beef (7), pork (6), sheep (1)
- **Sugar**
  -- sugar (1)

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Measuring diet cost has a long history

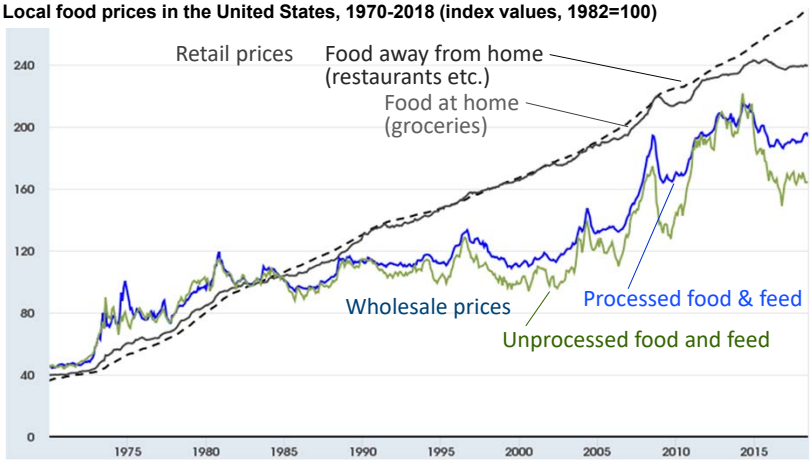
- For **foods actually consumed**, a *very* long history
  - Fleetwood (1707) food price index = 5 'quarters' of wheat, 4 'hogsheads' of beer
  - Lowe (1823) different baskets for different socioeconomic groups
  - Jevons (1865), Laspeyres (1871) and many others lead to modern CPI
- For **affordability of dietary energy**, a long history and wide use
  - Playfair (1821) chart of wheat prices and wages from 1565 to 1821
  - Sukhatme (1961) and FAO's Prevalence of Undernourishment in calories
  - Drewnowski (2004) measure of energy cost ($/kcal) and density (kcal/kg)
- For **nutrient adequacy**, more recent history and many specific uses
  - Stigler (1945) linear programming to compute least-cost diets
  - USDA *Thrifty Food Plan* for US nutrition assistance (1975, 1983, 1999, 2006)
  - SCUK *Cost of Diet tool* (2009) and FANTA et al. *Optifood* (2012) for aid programs
- For **next steps**, we introduce three new concepts:
  - A **nutritionally-weight price index** (using nutrient profile scores, from 1 to 100)
  - A **cost of diet diversity** index (at least one from each of at least 5 food groups)
  - A **cost of recommended diets** index (with quantities from local dietary guidelines)

We introduce four kinds of indicators to add up the cost of foods in terms of their *nutritional* values

- **Unit-free indexes** that track change over time
  - Nutritious-food Price Index (NPI)
    - Weight prices by profile scores, instead of expenditure shares as in CPI
  - Cost of Diet Diversity (CoDD)
    - Uses least-cost food from the lowest-cost food groups to reach MDD-W
- **Cost-per-day values** that specify quantities needed
  - Cost of a Recommended Diet (CoRD):
    - weights each price by quantities in the recommended diet
  - Cost of Nutrient Adequacy (CoNA):
    - the least-cost combination of foods to meet nutrient requirements
- **Applications reveal their advantages and disadvantages for policy analysis, program management, and research**

The price of each food depends on where and when it is bought

Local food prices in the United States, 1970-2018 (index values, 1982=100)



Source: US. Bureau of Labor Statistics, downloaded 21 July 2018.
Definitions and chart data are available at http://myf.red/g/kAoD

Several types of food price data are available

Ghana MoFA enumerator collecting food price data

Photo: Anna Herforth, 2017

- **All countries use food prices for their CPI**
- **Many also collect food prices for an MIS**
- **Sources differ in food lists and data quality**

	Market information & price monitoring	National accounts & poverty monitoring
Actor	Agricultural & food agencies	Financial & statistical agencies
Purpose	Inform farmers, traders, distributors	Measure real income, inflation, poverty
Products	Traded commodities, often a few key staple foods and cash crops at wholesale markets	Retail products, often a long list of over 50 standardized items from urban supermarkets
Access	Individual prices may be available upon request; Private sources charge for subscriptions	Aggregate indexes reported annually, quarterly or monthly; Item-level prices are sometimes confidential

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For nutritious diets, need diverse foods' prices

IANDA (2015-17) helped Ghana MoFA expand price monitoring to more foods

Cereals	White R&T	Plantain	Pulses	Nuts and Seeds	DGLV	Seed Oil
Maize	Yam	Plantain	Cowpea	Groundnut	**Nkontommire**	Coconut oil
Millet	Cocoyam		Soya bean	Groundnut (red)	**Jute mallow**	Palm oil
Sorghum	Cassava		**Bambara**	**Melon Seeds**	**Alefu (Amaranthus)**	Groundnut oil
Rice	Gari					
	Sweet potato					
	Cassava dough					
	Dried cassava					

Meat, Poultry and Fish	Vegetables	Fruits	Egg	Dairy
Beef	Tomato	Mango	Egg	**Fresh Cow Milk**
Pork	Garden Egg	Pineapple		
Salted dried fish	Okro	Palm fruit		
Live chicken bird	Onion	Watermelon		
Smoked herring	Ginger	Orange		
Anchovy	Pepper	Banana		
Fresh fish	**Cabbage**	**Coconut**		
Chicken meat	**Lettuce**	**Avocado**		
Snail	**Carrot**	**Pawpaw**		
Goat meat				
Mutton				

Ghana's MoFA market price reports will soon include the additional foods marked in red, for 20 major markets

To add up diverse foods, we can use nutrient profile scores (NuVal, NRF, SENS etc.)

We can use nutritional value instead of expenditure weights in a CPI

- Standard food CPI:
  - fCPI = $\sum_i p_i w_i$, where p_i and w_i are prices and weights in consumer spending
    - ➔ weights each price by quantities actually chosen
- Nutritious-food PI (NPI):
  - NPI = $\sum_i p_i n_i$, where n_i is a nutrient score, eg NuVaL from 1 (worst) to 100 (best)
    - ➔ weighting each expense by its nutritional value

- Nutrition scores aim to guide food choices
- We use them to measure whether more nutritious foods are becoming more or less affordable

A nutritious-food price index reflects a specific nutrition scoring system

Ghana Statistical Service CPI weights (food expenditure shares) versus NuVal scores (Nutritional Value index)

Used to measure real income & poverty (food as a whole is 42% of CPI)

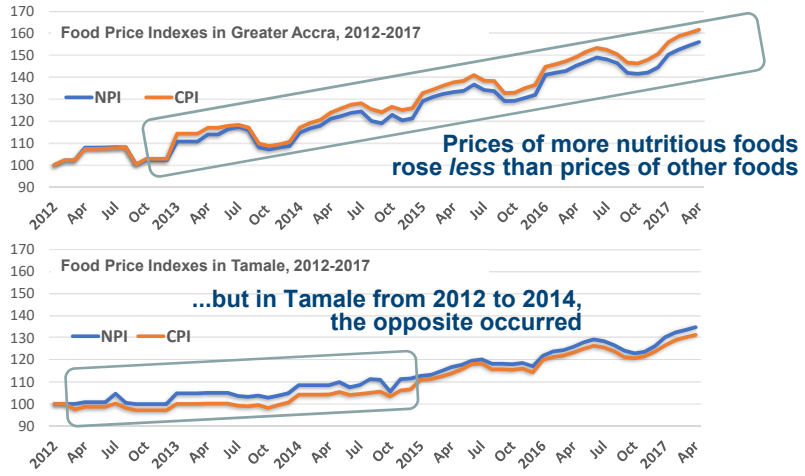
Could use to measure nutritional value

Food	CPI weights	NuVal weights
	100	*100*
Cereals and cereal products	25.55	19.43
Meat and meat products	9.10	8.55
Fish and sea food	22.93	14.12
Milk, cheese and eggs	4.33	5.50
Fruits	4.29	14.64
Vegetables	23.36	32.67
Oils and fats	5.19	0.86
Sugar, jam, honey, chocolate & confectionery	2.29	0.24
Mineral water, soft drinks, fruit &vegetable juices	3.57	0.45
Food products n.e.c.	1.95	2.45
Non-alcoholic beverages	5.57	2.50
Coffee, tea and cocoa	2.00	2.05

Nutritional value > consumer spending

Nutritional value < consumer spending

In Ghana, have more nutritious foods become more expensive than other foods?



Source: Author's calculation, from Ghana Statistical Service file data.

Another metric of diet quality is *diversity*

We follow the MDD-W

Minimum Dietary Diversity for Women
A Guide to Measurement

MDD-W is defined as ≥ 5 of these 10 food groups in past 24 hrs

(1) **Starchy staples** (Grains, white roots/tubers, plantains)

(2) **Pulses** (beans, peas and lentils – includes soybeans)

(3) **Nuts and seeds** (higher fat than pulses, includes groundnuts)

(4) **Flesh foods** (meat, poultry and fish)

(5) **Dark green leafy vegetables**

(6) **Other vitA-rich fruits & vegetables**

(7) **Other vegetables**; (8) **Other fruits**; (9) **Eggs**; (10) **Dairy**

We can measure the cost of reaching MDD-W with the least-cost food in each group

MDD-W has a direct economic interpretation

- Within groups, all foods are equal substitutes
- Each group meets different needs, and also contributes to energy balance
- Groups can be ranked by cost towards total daily energy balance
- People with at least five groups are likely to reach adequacy thresholds

The cost of reaching MDD-W can be defined as:

- Cost of Diet Diversity (CoDD):
  - $\text{CoDD} = \text{Min5}\{\min\{p_{i1}\}, \min\{p_{i2}\}, \ldots, \min\{p_{im}\}\}$
    - ➔ the least-cost way to include at least one food from at least 5 food groups
  - $\text{CoDD2} = \text{Ave}\{\min\{p_{i1}\}, \min\{p_{i2}\}, \ldots, \min\{p_{im}\}\}$
    - ➔ the least-cost way to include at least one food from *any* 5 of the 10 food groups

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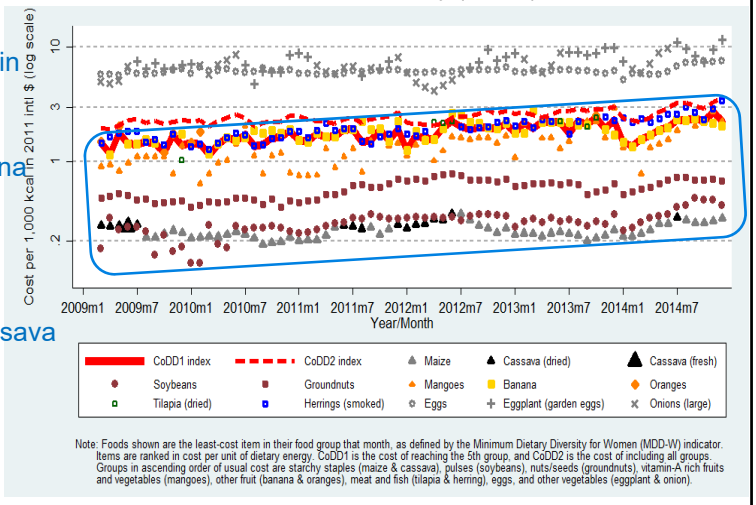
The least-cost food in each group may vary

Foods counted for the Cost of Diet Diversity (CoDD) in Ghana, 2009-14

In Ghana, foods in the five lowest-cost groups are:

5. Fish or banana
4. Mangoes
3. Groundnuts
2. Soya
1. Maize or cassava



Note: Foods shown are the least-cost item in their food group that month, as defined by the Minimum Dietary Diversity for Women (MDD-W) indicator. Items are ranked in cost per unit of dietary energy. CoDD1 is the cost of reaching the 5th group, and CoDD2 is the cost of including all groups. Groups in ascending order of usual cost are starchy staples (maize & cassava), pulses (soybeans), nuts/seeds (groundnuts), vitamin-A rich fruits and vegetables (mangoes), other fruit (banana & oranges), meat and fish (tilapia & herring), eggs, and other vegetables (eggplant & onion).

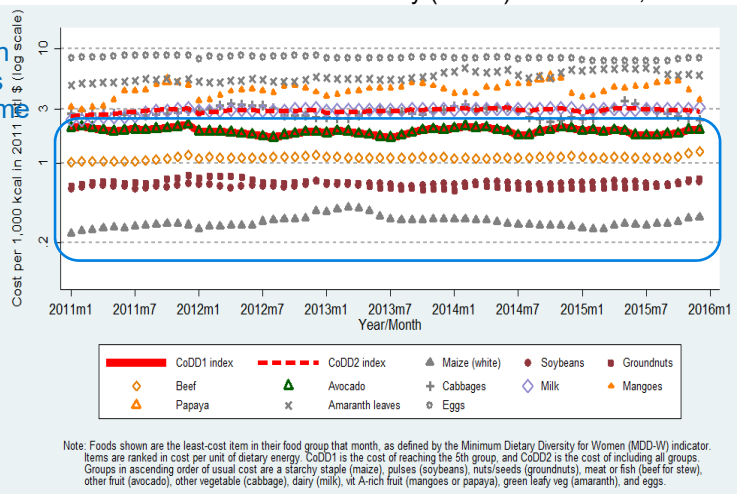
Source: Masters et al., (2018), "Measuring the Affordability of Nutritious Diets in Africa: Price Indexes for Diet Diversity and the Cost of Nutrient Adequacy". *AJAE*, forthcoming.

Each food group may have different trends and fluctuations

Foods counted for the Cost of Diet Diversity (CoDD) in Tanzania, 2011-15

In Tanzania, each food group varies differently over time

5.Avocado
4.Beef
3.Groundnuts
2.Soya
1.Maize



Note: Foods shown are the least-cost item in their food group that month, as defined by the Minimum Dietary Diversity for Women (MDD-W) indicator. Items are ranked in cost per unit of dietary energy. CoDD1 is the cost of reaching the 5th group, and CoDD2 is the cost of including all groups. Groups in ascending order of usual cost are a starchy staple (maize), pulses (soybeans), nuts/seeds (groundnuts), meat or fish (beef for stew), other fruit (avocado), other vegetable (cabbage), dairy (milk), vit A-rich fruit (mangoes or papaya), green leafy veg (amaranth), and eggs.

Source: Masters et al., (2018), "Measuring the Affordability of Nutritious Diets in Africa: Price Indexes for Diet Diversity and the Cost of Nutrient Adequacy". *AJAE*, forthcoming.

To measure cost levels (e.g. $/day), we can use the Cost of a Recommended Diet (CoRD)

The previous indexes are unit-free, to measure *change over time*

- Traditional food CPI
- Nutritious-food CPI (NPI)
- Cost of Diet Diversity (CoDD)

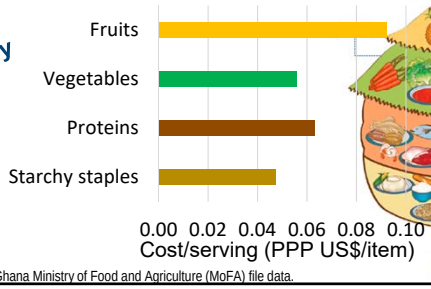
We measure total cost by specifying quantities consumed

- Cost of a Recommended Diet (CoRD):
  - CoRD = $\sum_j p_{ij} q_j$, where $p_{ij} = \min\{p_{ij}\}$ and q_j = requirement for $j=\{1,\ldots, m\}$ categories
    - ➔ weights each price by quantities in the recommended diet, **lowest-cost only**
  - CoRD2 = $\sum_j p_{ij} q_j$, where $p_{ij} = \textbf{median}\{p_{ij}\}$ and q_j = requirement for $j=\{1,\ldots, m\}$ categories
    - ➔ weights each price by quantities in the recommended diet, **all foods equally**

The Cost of a Recommended Diet (CoRD) reflects specific dietary guidelines

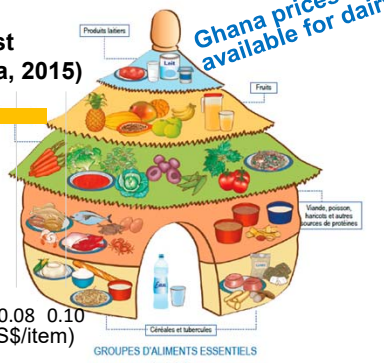
In Africa, the only countries with dietary guidelines are Benin, Sierra Leone, Nigeria, Namibia, and South Africa (+Kenya soon)

Cost per serving for lowest-cost item in each food group (Ghana, 2015)



Guidelines specify the number of servings in each group

Ghana prices not available for dairy



Source: Author's calculation, from Ghana Ministry of Food and Agriculture (MoFA) file data.

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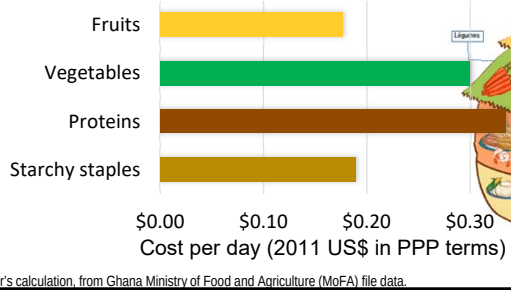
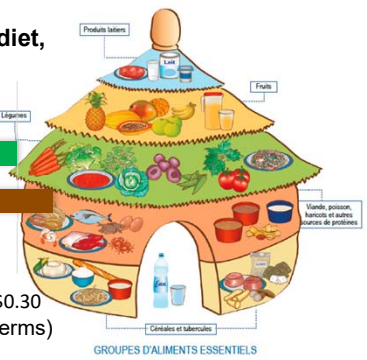
The Cost of a Recommended Diet (CoRD) depends on which foods are used

With the median item in each food group (except dairy), total cost would be US$1.37/day

Ghana price data include several high-cost vegetables and protein foods, so those groups can be very expensive

Cost per day for a recommended diet, median of all items (Ghana, 2015)



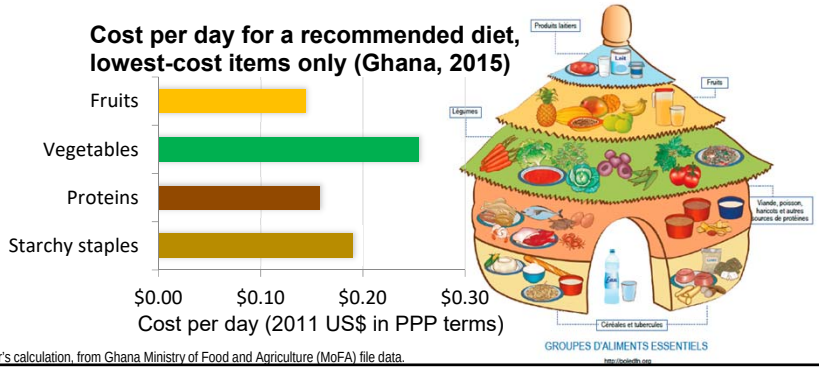


Source: Author's calculation, from Ghana Ministry of Food and Agriculture (MoFA) file data.

The Cost of a Recommended Diet (CoRD) depends on price and quantity per day

With the lowest-cost items in each food group (except dairy), total cost would be US$0.75/day

The required portions from each food group cost between $0.15 and $0.25 per day



Source: Author's calculation, from Ghana Ministry of Food and Agriculture (MoFA) file data.

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The most widely-used gold standard for diet quality remains nutrient adequacy

The Cost of Nutrient Adequacy (CoNA) is a "least-cost diet" using foods that reach EARs at lowest cost:

Minimize $C = \Sigma_i p_i q_i$

Subject to $a_{ij}\, q_i > EAR_j$, for j = 1,…, 17 essential nutrients

and $a_{ie}\, q_i = E$, for energy

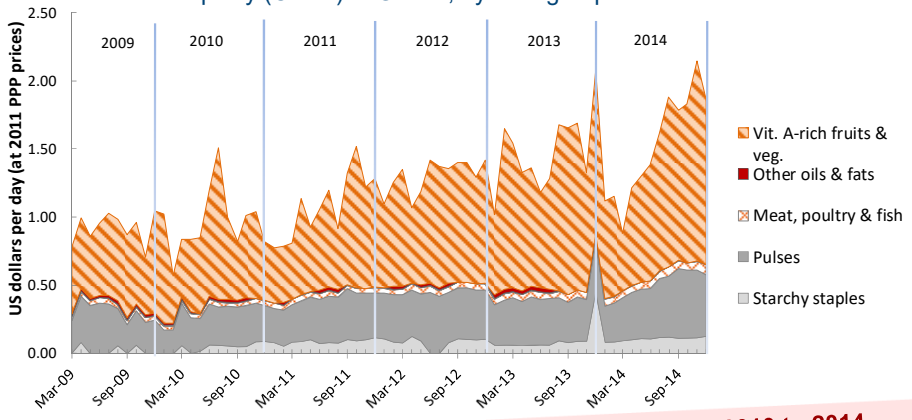
where p_i is price and q_i is quantity of food i, and a_{ij} is its content in nutrient j, for which EAR_j is the Estimated Average Requirements for adult women aged 19-30, not pregnant or lactating, at 55 kg with energy use (E) of 2000 kcal/day

We focus on total cost

- Disaggregated by food groups, to show diet composition
- Disaggregated by nutrients, valued at their shadow prices

In the Ghana data, vitamin A is very expensive

Cost of Nutrient Adequacy (CoNA) in Ghana, by food group



In Ghana, the cost of buying sufficient nutrients rose from 2010 to 2014, largely because vitamin-A rich F&V (e.g. mango) became more expensive

Source: Masters et al., (2018), "Measuring the Affordability of Nutritious Diets in Africa: Price Indexes for Diet Diversity and the Cost of Nutrient Adequacy". *AJAE*, forthcoming.

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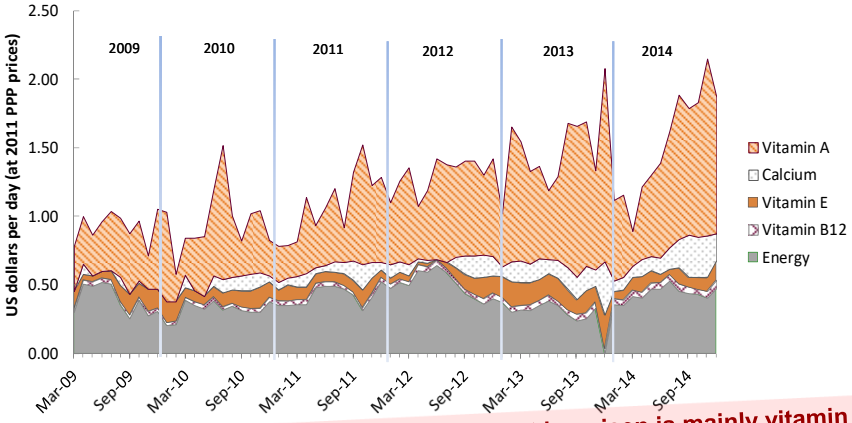
In Ghana, limiting nutrients after vitamin A are energy, calcium, vitamin E & vitamin B12

Cost of Nutrient Adequacy (CoNA) in Ghana, by limiting nutrient

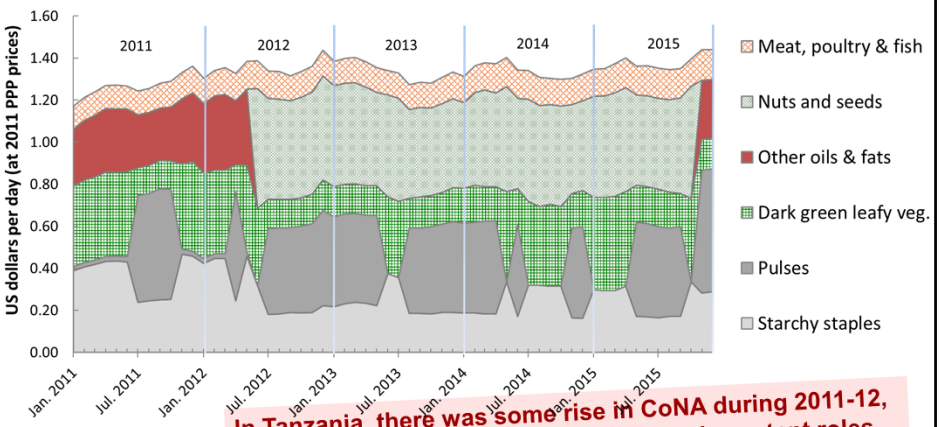


In Ghana, the limiting nutrient whose cost has risen is mainly vitamin A, but the cost of meeting calcium requirements has also risen

Source: Masters et al., (2018), "Measuring the Affordability of Nutritious Diets in Africa: Price Indexes for Diet Diversity and the Cost of Nutrient Adequacy". *AJAE*, forthcoming.

In the Tanzania data, more different foods sometimes enter the least-cost diet

Cost of Nutrient Adequacy (CoNA) in Tanzania, by food group



In Tanzania, there was some rise in CoNA during 2011-12, with many different food groups playing important roles

Source: Masters et al., (2018), "Measuring the Affordability of Nutritious Diets in Africa: Price Indexes for Diet Diversity and the Cost of Nutrient Adequacy". *AJAE*, forthcoming.

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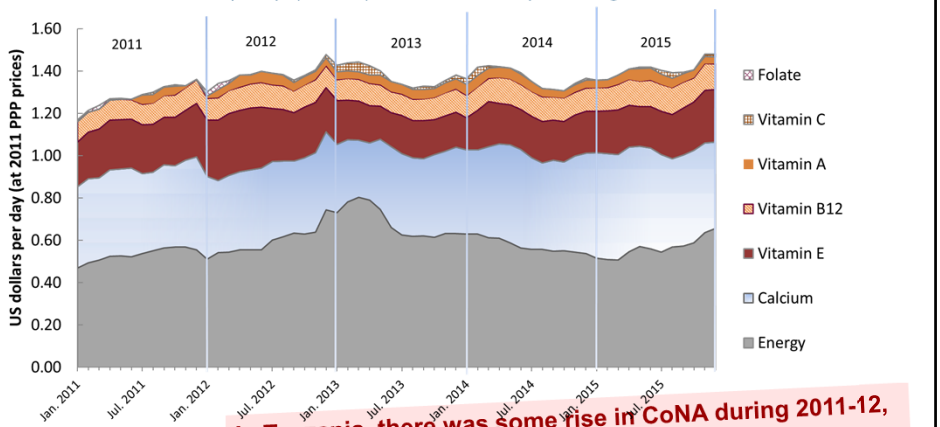
In Tanzania, limiting nutrients are same as Ghana, plus vitamin C & folate

Cost of Nutrient Adequacy (CoNA) in Tanzania, by limiting nutrient

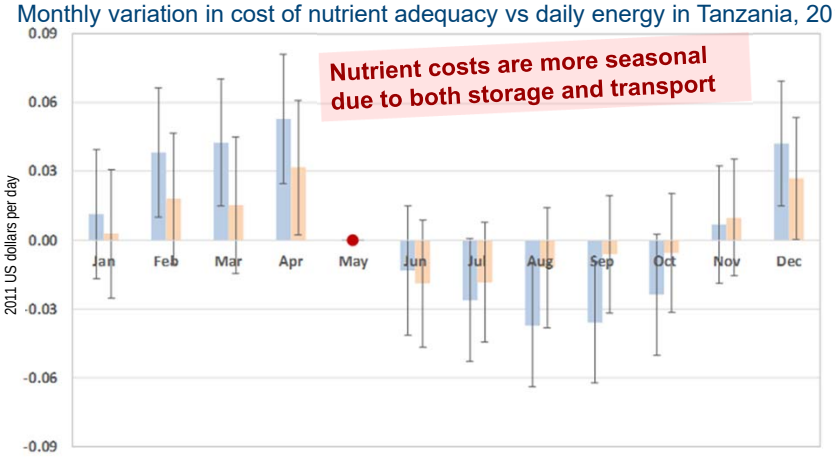


In Tanzania, there was some rise in CoNA during 2011-12, with many different nutrients as limiting factors

Source: Masters et al., (2018), "Measuring the Affordability of Nutritious Diets in Africa: Price Indexes for Diet Diversity and the Cost of Nutrient Adequacy". *AJAE*, forthcoming.

Application #1: Seasonality in the cost of nutritious diets vs. cost of daily energy

Monthly variation in cost of nutrient adequacy vs daily energy in Tanzania, 2011-15



Note: Data shown are coefficient and 95% confidence interval on calendar month indicators, relative to May. Orange bars for cost of calorie adequacy (CoCA) not significantly different from zero.

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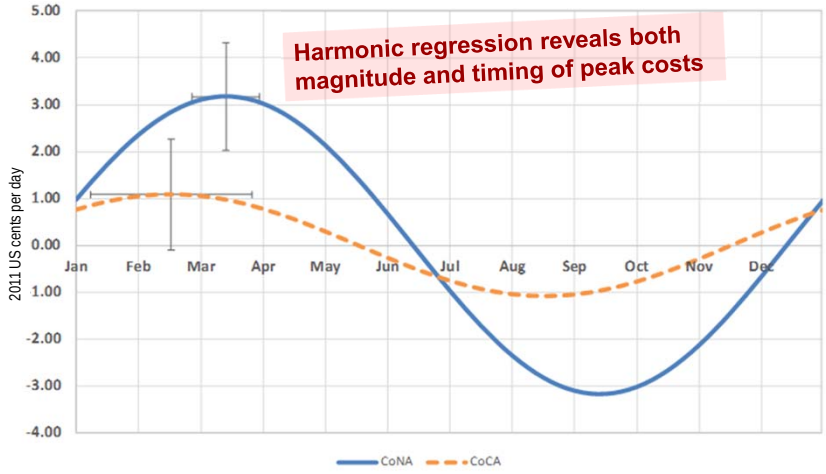
Source: Bai, Naumova and Masters (2018), Seasonality in Food Prices and the Cost of a Nutritious Diet in Tanzania. Working paper, forthcoming.

Application #1: Seasonality in diet costs can be summarized by a single variable

Harmonic regression results for cost of nutrient adequacy in Tanzania, 2011-15



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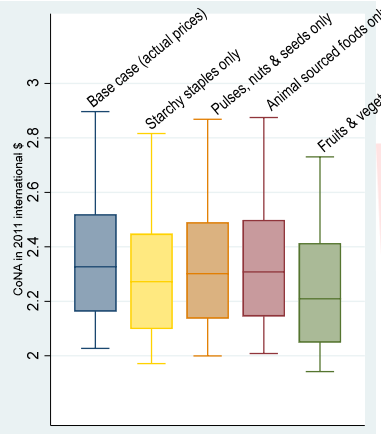
Source: Bai, Naumova and Masters (2018), Seasonality in Food Prices and the Cost of a Nutritious Diet in Tanzania. Working paper, forthcoming.

Application #2: Ghana's PFJ program could have more impact if it included F&V

Impact on cost of nutrients of 10% price reductions by food group in Ghana, 2011-15



In reality, Ghana's "Planting for Food and Jobs" program excludes fruits and vegetables

Source: Sarpong, Bai, Mishili and Masters (2018), Impacts of Agricultural and Trade Policy on the Cost of Nutritious Diets in Ghana and Tanzania. Framework paper for AERC AFPON project, forthcoming.

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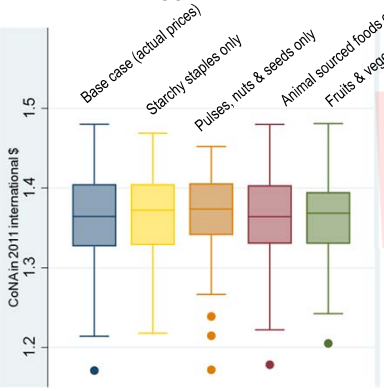
Application #2: Tanzania's marketing policies could reduce disparities in cost of nutrients by targeting pulses, nuts & seeds

Impact on cost of nutrients of 50% s.d. reductions by food group in Tanzania, 2009-14



Our whole-of-diet approach reveals how improvements in one food group leads other groups to become binding constraint

Source: Sarpong, Bai, Mishili and Masters (2018), Impacts of Agricultural and Trade Policy on the Cost of Nutritious Diets in Ghana and Tanzania. Framework paper for AERC AFPON project, forthcoming.

Conclusions and next steps

- We provide economic price indexes corresponding to nutritionists' definitions of a healthy diet:
  - Nutrient profile scores for individual foods, modifying CPI to calculate **NPI**
  - Minimum recommended diets, using dietary guidelines to calculate **CoRD**
  - Minimum dietary diversity levels, using MDD-W to calculate **CoDD**
  - Minimum (and max.) nutrient levels, using DRIs to calculate **CoNA**
- For research, the gold standard remains nutrient adequacy
  - Initial applications include:
    - Seasonality in the added cost of nutrient adequacy over daily energy
    - Policy-induced changes in average levels and also disparities in diet cost
    - International differences associated with national income and urbanization
- For policy and programs, simpler measures are useful too
  - Ghana Statistical Service (GSS) and Min of Food & Ag (MoFA) officials intend to add NPI and CoRD to their monthly reports

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Thank you!

The CANDASA project is funded by UKAid and the Bill & Melinda Gates Foundation (OPP1182628). It is implemented at Tufts and IFPRI in Washington, Delhi and Addis, with academic partners in Ghana, Tanzania, and Malawi, and includes collaborations with ARENA, AFPON, and the ANH Academy.

Software tools will be published on the Gates Open Research platform, and also available on the project website at **http://sites.tufts.edu/candasa**

Special thanks to all price enumerators

Tufts UNIVERSITY

UKaid from the British people