The Cost of (Un)Healthy Diets: Novel Food Price Indexes Based on Nutritional Attributes

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The Cost of (Un)Healthy Diets: Novel Food Price Indexes

motivation | food scores | diet diversity | recommended diets | nutrient adequacy | conclusion

Adding up foods
in terms of nutritional values
is of great interest to economists

• Allen (2017) in AER uses cost of nutrient adequacy to measure global poverty
  – This works only for “under” nutrition, and counts only some nutrients
Adding up foods in terms of nutritional values is of great interest to economists

- Allen (2017) in AER uses cost of nutrient adequacy to measure global poverty
  - This works only for "under" nutrition, and counts only some nutrients

  - This doesn’t reflect differences in importance among nutrients

As food environments change, are healthy diets as defined by nutritionists becoming easier to buy, or further out of reach?
Here we compare 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 **nutrient scores**, instead of spending level 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**

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How might we measure the cost and affordability of a nutritious diet?

- 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
  - SCUK Cost of Diet tool (2009) and FANTA et al. Optifood (2012) for aid programs

- We also introduce three new concepts:
  - A **nutritionally-weight price index** (using NuVal points, 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)
Food prices can come from many different sources

How are food prices now being collected and used?

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

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The IANDA project helped Ghana MoFA expand price data collection to include more diverse foods

<table>
<thead>
<tr>
<th>Cereals</th>
<th>White Roots and Tubers</th>
<th>Plantain</th>
<th>Pulses</th>
<th>Nuts and Seeds</th>
<th>Dark Green Leafy Vegetables</th>
<th>Seed Oil</th>
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</thead>
<tbody>
<tr>
<td>Maize</td>
<td>Yam</td>
<td>Plantain</td>
<td>Cowpea (white)</td>
<td>Groundnut (unsh)</td>
<td>Nkontommire</td>
<td>Coconut oil</td>
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<tr>
<td>Millet</td>
<td>Cocoyam</td>
<td>Soya bean</td>
<td>Groundnut (red)</td>
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<td>Jute mallow</td>
<td>Palm oil</td>
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<tr>
<td>Sorghum</td>
<td>Cassava</td>
<td>Bambara Bean</td>
<td>Melon Seeds</td>
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<td>Alefu (Amaranthus)</td>
<td>Groundnut oil</td>
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<td>Rice</td>
<td>Gari</td>
<td>Sweet potato</td>
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<td>Cassava dough</td>
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<td>Dried cassava</td>
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<tr>
<td>Meat, Poultry and Fish</td>
<td>Vegetables</td>
<td>Fruits</td>
<td>Egg</td>
<td>Dairy</td>
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<tr>
<td>Beef</td>
<td>Tomato</td>
<td>Mango</td>
<td>Egg</td>
<td>Fresh Cow Milk</td>
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<tr>
<td>Pork</td>
<td>Garden Egg</td>
<td>Pineapple</td>
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<td>Salted dried fish</td>
<td>Okro</td>
<td>Palm fruit</td>
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<td>Live chicken bird</td>
<td>Onion</td>
<td>Watermelon</td>
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<td>Smoked herring</td>
<td>Ginger</td>
<td>Orange</td>
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<td>Anchovy</td>
<td>Pepper</td>
<td>Banana</td>
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<td>Fresh fish</td>
<td>Cabbage</td>
<td>Coconut</td>
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<tr>
<td>Chicken meat</td>
<td>Lettuce</td>
<td>Avocado</td>
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<td>Snail</td>
<td>Carrot</td>
<td>Pawpaw</td>
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<td>Goat meat</td>
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<td>Mutton</td>
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Standard food CPI counts each food in proportion to actual consumption

We can use nutrition scores instead

- **Standard food CPI:**
  \[
  ICPI = \sum p_i w_i,
  \]
  where \( p_i \) and \( w_i \) are prices and weights in consumer spending
  
  weights each price by quantities actually chosen

- **Nutritious-food PI (NPI):**
  \[
  NPI = \sum p_i n_i w_i,
  \]
  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

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

- Prices of more nutritious foods rose less than prices of other foods
- But in Tamale from 2012 to 2014, the opposite occurred
A popular 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**

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

- Cost of Diet Diversity (CoDD):
  - \( \text{CoDD} = \text{Min}5\{\text{min}\{p_1\}, \text{min}\{p_2\}, \ldots, \text{min}\{p_m\}\} \)
  - the least-cost way to include at least one food from at least 5 food groups
  - \( \text{CoDD2} = \text{Ave}\{\text{min}\{p_1\}, \text{min}\{p_2\}, \ldots, \text{min}\{p_m\}\} \)
  - the least-cost way to include at least one food from any 5 of the 10 food groups
The least-cost food in each group may vary

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

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

The Cost of Diet Diversity (CoDD) in Ghana, 2009-14

Note: if we ranked foods by weight ($/kg), the least cost starchy staple would always be cassava

Each food group may have different trends and fluctuations

In Tanzania, each food group varies differently over time

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

The Cost of Diet Diversity (CoDD) in Tanzania, 2011-15

Note: if we ranked foods by weight ($/kg), the least cost food would often be cabbage
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):
  
  \[ \text{CoRD} = \sum_{j} p_{ij} q_{j} \], where \( p_{ij} = \min \{ p_{ij} \} \) and \( q_{j} \) = requirement for \( j = \{1, \ldots, m\} \) categories
  
  \( \Rightarrow \) weights each price by quantities in the recommended diet, lowest-cost only

  \[ \text{CoRD2} = \sum_{j} p_{ij} q_{j} \], where \( p_{ij} = \text{median} \{ p_{ij} \} \) and \( q_{j} \) = requirement for \( j = \{1, \ldots, m\} \) categories
  
  \( \Rightarrow \) weights each price by quantities in the recommended diet, all foods equally

The required portions from each food group cost between $0.15 and $0.25 per day
The Cost of Nutrient Adequacy (CoNA) is a “least-cost diet” using foods that reach EARs at lowest cost:

Minimize \( C = \sum p_i q_i \)

Subject to \( a_{ij} q_i > \text{EAR}_j \), for \( j = 1, \ldots, 17 \) essential nutrients

and \( a_{ew} q_i = E \), 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 \( \text{EAR}_j \) 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 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
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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.

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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 in keeping the cost of nutrients relatively stable.
Conclusions and next steps

- Calculating the cost of a nutritious diet is challenging
  - Need clear definition of “nutritious”. Here we use:
    - Food scores for nutritional value, modifying standard CPI to calculate NPI
    - Recommended diets, using dietary guidelines to calculate CoRD
    - Dietary diversity, using MDD-W to calculate CoDD
    - Nutrient adequacy, using use EARs for 17 nutrients to calculate CoNA

- Underlying data remain limiting
  - Here, we use prices from MoFA in Ghana, NBS in Tanzania
  - For Ghana, future studies will include prices for expanded food list
  - In Tanzania and other countries, need more rural market prices

- Our ongoing CANDASA project will:
  - Assemble prices from additional countries
  - Test link to prices from climate fluctuations, infrastructure & markets
  - Test link from prices to diet quality, heights & weights

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

This work is funded by UKAid and the Bill & Melinda Gates Foundation (OPP1182628).

Model code and data for replication of results will be available on that project’s website at http://sites.tufts.edu/candasa.

All results depend on price enumerators!

Photo: Anna Herforth, 2017

Other slides
Existing food price indexes are weighted by market value and say little about nutritional value

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)

Source: www.fao.org/worldfoodsituation, 29 Sept. 2017

Within a consumer price index, food price trends and fluctuations differ greatly by type of food

Local food prices in the United States, 1970-2016 (index values, 1982=100)

Summary of formulas

Index values: unit-free, no quantities specified

• Nutritious-food CPI (NPI):
  \[ \text{NPI} = \sum p_i n_i \], where \( n_i \) is a food’s health score, eg NuVaL from 1 (worst) to 100 (best)
  ➔ weighting each price by its nutritional value, instead of expenditure shares in CPI

• Cost of Diet Diversity (CoDD):
  \[ \text{CoDD} = \text{Min}_5 \{\text{min} \{p_{i1}\}, \text{min} \{p_{i2}\}, \ldots, \text{min} \{p_{im}\}\} \]
  ➔ the least-cost way to include at least one food from at least 5 food groups
  \[ \text{CoDD2} = \text{Ave} \{\text{min} \{p_{i1}\}, \text{min} \{p_{i2}\}, \ldots, \text{min} \{p_{im}\}\} \]
  ➔ the least-cost way to include at least one food from any 5 of the 10 food groups

Cost per day: specifies quantities needed

• Cost of a Recommended Diet (CoRD):
  \[ \text{Cost of a Recommended Diet (CoRD)} = \sum p_i q_j \], where \( p_i = \text{min} \{p_{ij}\} \) and \( q_j \) = requirement for \( j = \{1, \ldots, m\} \) categories
  ➔ weights each price by quantities in the recommended diet, lowest-cost only

• Cost of Nutrient Adequacy (CoNA):
  \[ \text{Cost of Nutrient Adequacy (CoNA)} = \text{Min}_i \sum p_i a_{ij} q_i \], where \( a_{ij} q_i > \text{EAR}_j \) and \( a_{ij} q_i = E \)
  ➔ the least-cost combination of \( m \) foods to meet \( n \) nutrient needs