

# 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



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The Geography of Poverty and Nutrition: Food Deserts and Food Choices Across the United States

- Allcott et al (2017) uses deviation from US Dietary Guidelines
  - This doesn't reflect differences in importance among nutrients

Hunt Allcott, Rebecca Diamond, Jean-Pierre Dubé

NBER Working Paper No. 24094  
Issued in December 2017

NBER Program(s): Health Economics, Industrial Organization,  
Public Economics

## As food environments change, are healthy diets as defined by nutritionists becoming easier to buy, or further out of reach?



Photo: Anna Herforth, at Nsawam market, Ghana

## 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

## 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
  - 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
- 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



Ghana MoFA enumerator collecting food price data

### How are food prices now being collected and used?

	Market information & price monitoring	National accounts & poverty monitoring
<b>Actor</b>	Agricultural & food agencies	Financial & statistical agencies
<b>Purpose</b>	Inform farmers, traders, distributors	Measure real income, inflation, poverty
<b>Products</b>	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
<b>Access</b>	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

Photo: Anna Herforth, 2017

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

Cereals	White Roots and Tubers	Plantain	Pulses	Nuts and Seeds	Dark Green Leafy Vegetables	Seed Oil
Maize	Yam	Plantain	Cowpea (white)	Groundnut (unsh)	<b>Nkontommire</b>	Coconut oil
Millet	Cocoyam		Soya bean	Groundnut (red)	<b>Jute mallow</b>	Palm oil
Sorghum	Cassava		<b>Bambara Bean</b>	<b>Melon Seeds</b>	<b>Alefu (Amaranthus)</b>	Groundnut oil
Rice	Gari					
	Sweet potato					
	Cassava dough					
	Dried cassava					

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

Ghana's Weekly Market Price Reports will soon include the additional foods marked in red, for 20 major markets

## Standard food CPI counts each food in proportion to actual consumption

### We can use nutrition scores instead

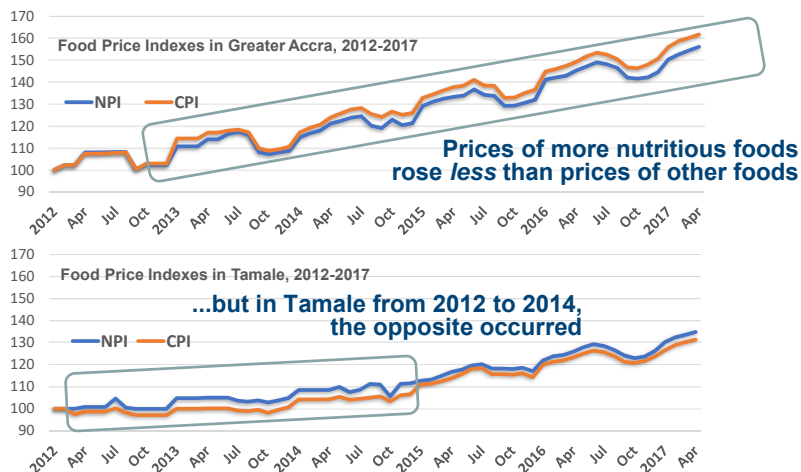
- Standard food CPI:
  - $fCPI = \sum_i p_i w_i$ , where  $p_i$  and  $w_i$  are prices and weights in consumer spending  
 → weights each price by quantities actually chosen
- Nutritious-food PI (NPI):
  - $NPI = \sum_i p_i n_i w_i$ , where  $n_i$  is a nutrient score, eg NuVaL from 1 (worst) to 100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



VEGETABLES	
100	BROCCOLI
98	CELERY
100	CAULIFLOWER
98	CHERRY TOMATOES
100	ROMAINE LETTUCE
94	GREEN PEPPERS
100	BABY SPINACH
93	CUCUMBERS
99	CARROTS
82	ICEBURG LETTUCE

The Higher The NuVal® Score,  
The Better The Nutrition.

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



## 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  $\geq 5$  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:

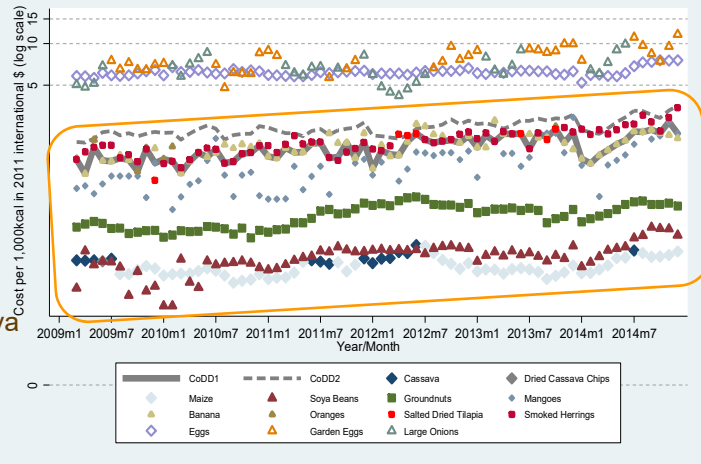
- **Cost of Diet Diversity (CoDD):**
  - $\text{CoDD} = \text{Min5} \{ \min \{ p_{i1} \}, \min \{ p_{i2} \}, \dots, \min \{ p_{im} \} \}$   
→ the least-cost way to include at least one food from at least 5 food groups
  - $\text{CoDD2} = \text{Ave} \{ \min \{ p_{i1} \}, \min \{ p_{i2} \}, \dots, \min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

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



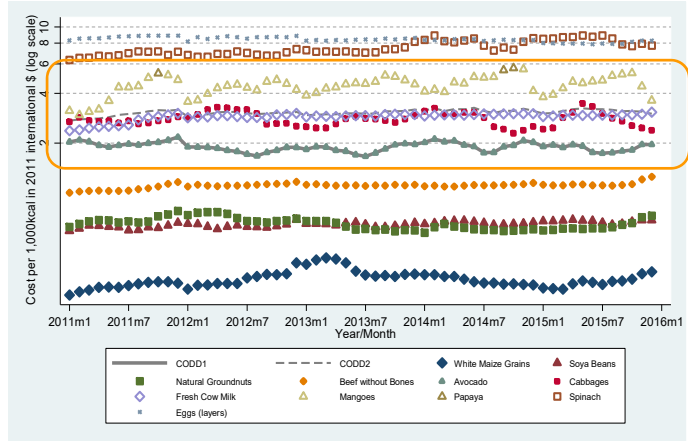
Note: if we ranked foods by weight (\$/kg), the least cost starchy staple would always be cassava

## Each food group may have different trends and fluctuations

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: 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

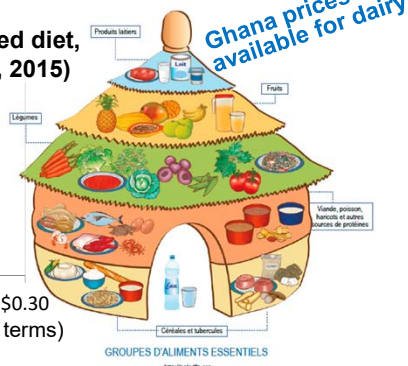
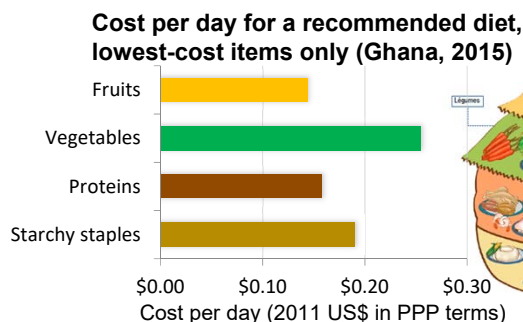
- Cost of a Recommended Diet (CoRD):
  - $CoRD = \sum_j p_{ij} q_j$ , where  $p_{ij} = \min\{p_{ij}\}$  and  $q_j =$  requirement for  $j = \{1, \dots, m\}$  categories  
 → weights each price by quantities in the recommended diet, **lowest-cost only**
  - $CoRD2 = \sum_j p_{ij} q_j$ , where  $p_{ij}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

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

With the average of all 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

République du Bénin  
 MINISTÈRE DE L'AGRICULTURE, DU PÊCHE ET DE LA PASTORALE  
 CONSEIL NATIONAL DE LA NUTRITION (CNA)  
 Guide alimentaire du Bénin





## The most widely-used nutritional standard is nutrient adequacy

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

$$\text{Minimize } C = \sum_i p_i q_i$$

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

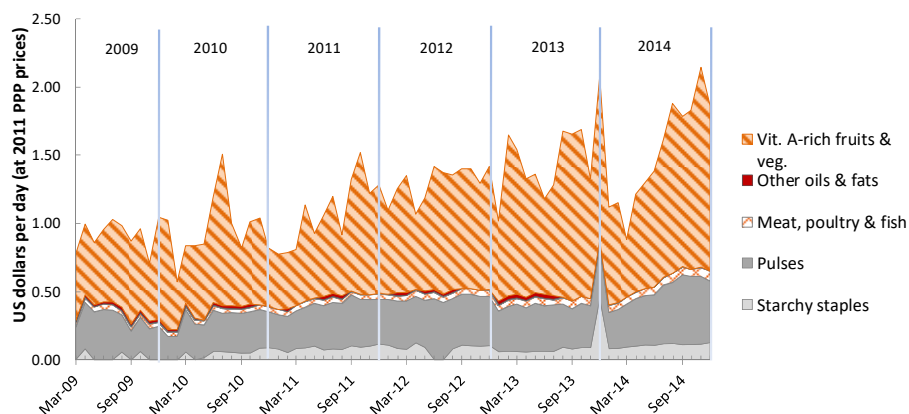
and  $a_{ie} q_i = E$ , for energy

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

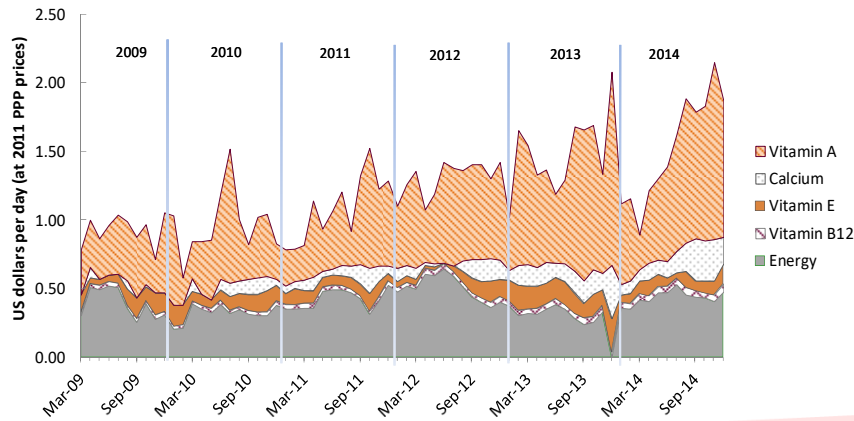
- Disaggregated by food groups, to show diet composition
- Disaggregated by nutrients, valued at their shadow prices

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



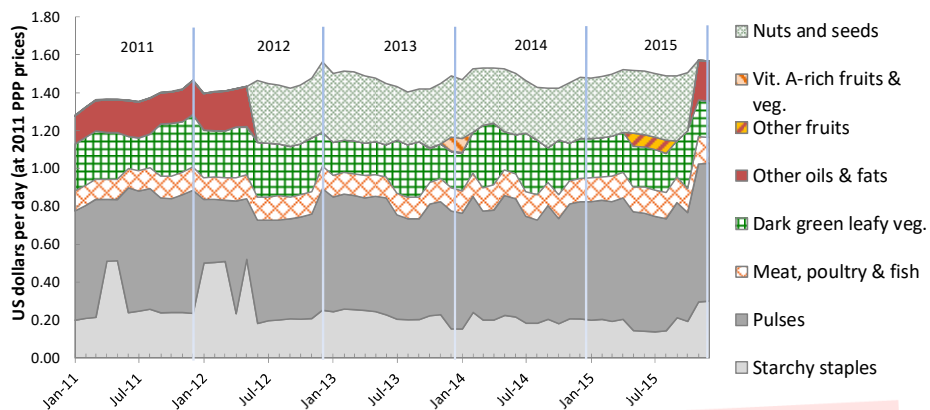
**In Ghana, the cost of buying sufficient nutrients rose from 2010 to 2014, largely because vitamin-A rich F&V (e.g. mango) became more expensive**

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



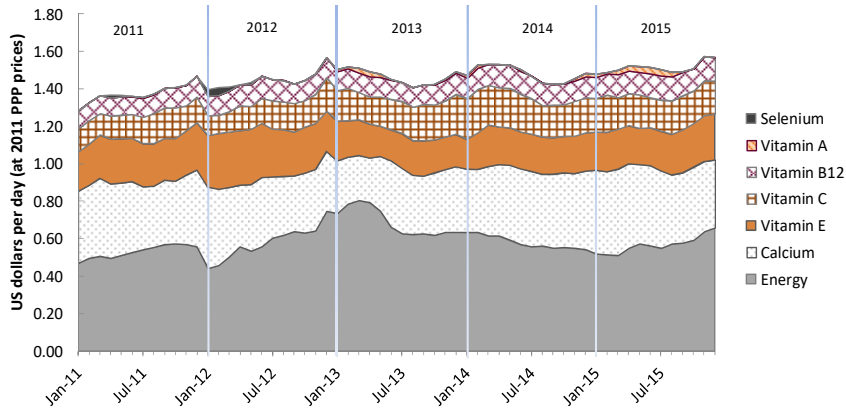
**In Ghana, the limiting nutrient whose cost has risen is mainly vitamin A, but the cost of meeting calcium requirements has also risen**

### 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**

### 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**

### 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

**The Cost of (Un)Healthy Diets: Novel Food Price Indexes**  
motivation | formulas | data | nutrient adequacy | diet diversity | next steps

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!



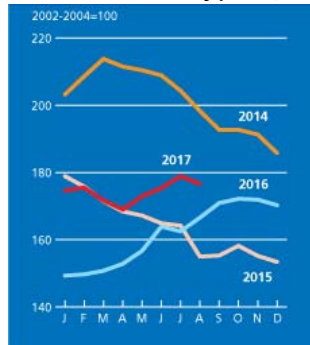
Photo: Anna Herforth, 2017



Other slides

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

World food commodity prices, 2014-2017



Source: [www.fao.org/worldfoodsituation](http://www.fao.org/worldfoodsituation), 29 Sept. 2017

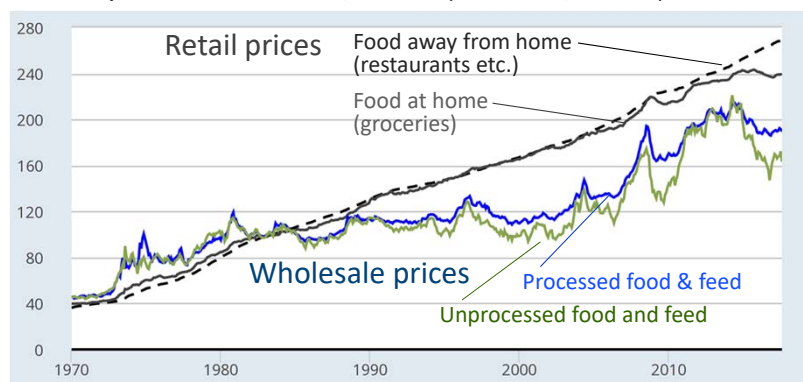
For global commodity prices, the FAO Food Price Index consists of five commodity group price indices, weighted with average export shares of each of the groups for 2002-2004.

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)

## 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)



Source: US. Bureau of Labor Statistics, downloaded 29 Sept. 2017.  
 Definitions and chart data are available at <http://myf.red/g/ff6v>

## Summary of formulas

Index values: unit-free, no quantities specified

- Nutritious-food CPI (NPI):
  - $NPI = \sum_i p_i n_i$ , 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):
  - $CoDD = \text{Min5} \{ \min \{ p_{i1} \}, \min \{ p_{i2} \}, \dots, \min \{ p_{im} \} \}$ 
    - the least-cost way to include at least one food from at least 5 food groups
  - $CoDD2 = \text{Ave} \{ \min \{ p_{i1} \}, \min \{ p_{i2} \}, \dots, \min \{ p_{im} \} \}$ 
    - 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):
  - $CoRD = \sum_j p_{ij} q_j$ , where  $p_{ij} = \min \{ p_{ij} \}$  and  $q_j =$  requirement for  $j = \{1, \dots, m\}$  categories
    - weights each price by quantities in the recommended diet, **lowest-cost only**
- Cost of Nutrient Adequacy (CoNA):
  - $CoNA = \text{Min}_i \sum_j p_j q_j$ , where  $a_{ij} q_j > EAR_j$  and  $\sum_i a_{ij} q_j = E$ 
    - $a_{ij}$  is nutrient content of foods,  $EAR_j$  is nutrient requirement of people
    - the least-cost combination of  $m$  foods to meet  $n$  nutrient needs