Seasonality in the cost of nutritious diets by region in Tanzania

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Brief abstract (150 words):
This paper measures seasonal variation in the affordability of healthy diets across regions of Tanzania, to identify which nutrients and foods account for differences in seasonality and test whether infrastructure and market access can help stabilize access to nutritious foods. Our outcome of interest is the real cost of meeting nutrient requirements at local market prices. We isolate seasonality from other shocks using harmonic regression, and find that variation is most often driven by fluctuations in the cost of meeting micronutrient needs through fruits and vegetables. Fewer regions have significant seasonality in the cost of meeting daily energy requirements, but those fluctuations are larger in magnitude than the cost of micronutrients. Results operationalize the distinction between food security and nutrition security, pointing to opportunities for more targeted investments in fruit and vegetable markets to lower and smooth the cost of micronutrients, alongside continued investment in starchy staples for daily energy.

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Seasonality in the cost of nutritious diets by region in Tanzania

This paper measures seasonal variation in the affordability of healthy diets across regions of Tanzania, comparing seasonality in the cost of acquiring each essential nutrient in addition to daily energy requirements. We aim to identify which nutrients and foods account for differences in seasonality, and test whether infrastructure and market access can help stabilize access to a nutritious diet. The result allows researchers and policy analysts to distinguish nutrition security from food security, using data on food composition, food prices, and the nutrient needs of vulnerable populations.

To our knowledge this is the first study of seasonality to address the cost of a complete diet, allowing for substitution among items as their relative prices change. Previous work on seasonality has focused on individual foods and specific health outcomes. Here we capture substitution possibilities in overall needs through a least-cost diet, providing just enough essential nutrients for a healthy and active life. Actual diets also meet other goals such as convenience and taste, and also may fall short of nutrient requirements. Using a least-cost diet as the benchmark allows us to compare seasonality in the cost of nutrients beyond calories, measuring their affordability for the poorest and most at risk of malnutrition.

We isolate seasonality from other shocks using harmonic regression over a 4-year time period (2011-15), extracting one specific kind of variation to be compared across regions. Seasonal variation is of particular interest as a predictable and potentially avoidable kind of shock that has severe consequences for the rural poor, due to low diversification and limited ability to smooth intake over time. Seasonality in food prices reflects the net result of variation in local production, consumption, storage and trade. Market development generally reduces seasonality through declining relative costs of storage and trade, making seasonal variation a useful measure of spatial differences in the food environment.

Seasonality in prices is closely tied to spatial integration, as trade and storage fill arbitrage opportunities between production centers, coastal cities and local markets. For this study we extract the seasonal component of fluctuations by harmonic (trigonometric) regression for each location, of the form:

$$\ln(C_{ikt}) = \alpha_0 + a\sin(2\pi\omega t) + b\cos(2\pi\omega t) + \beta t + \gamma_i F_i + \vartheta_j R_j \qquad (1)$$

where C_{ijt} is the cost of food i in region k at time t in a monthly time series from Jan 2011 to Dec 2015. Coefficients on the sine and cosine terms, a and b, measure the magnitude of seasonality where ω is a constant equal to 1/12 indicating 12 months per annual cycle, while F_i and R_j are fixed effects used in some regressions for food items and regions, and β controls for a linear time trend, if any. In the analysis, we focus on the amplitude of seasonal variation $A = \delta\sqrt{a^2 + b^2}$, where δ=1 if b>0, and -1 if b<0, normalized to a unit-free percentage of each food's price at its lowest time of year.

For the overall cost of meeting nutrient needs, we use a least-cost diet defined as the solution to:

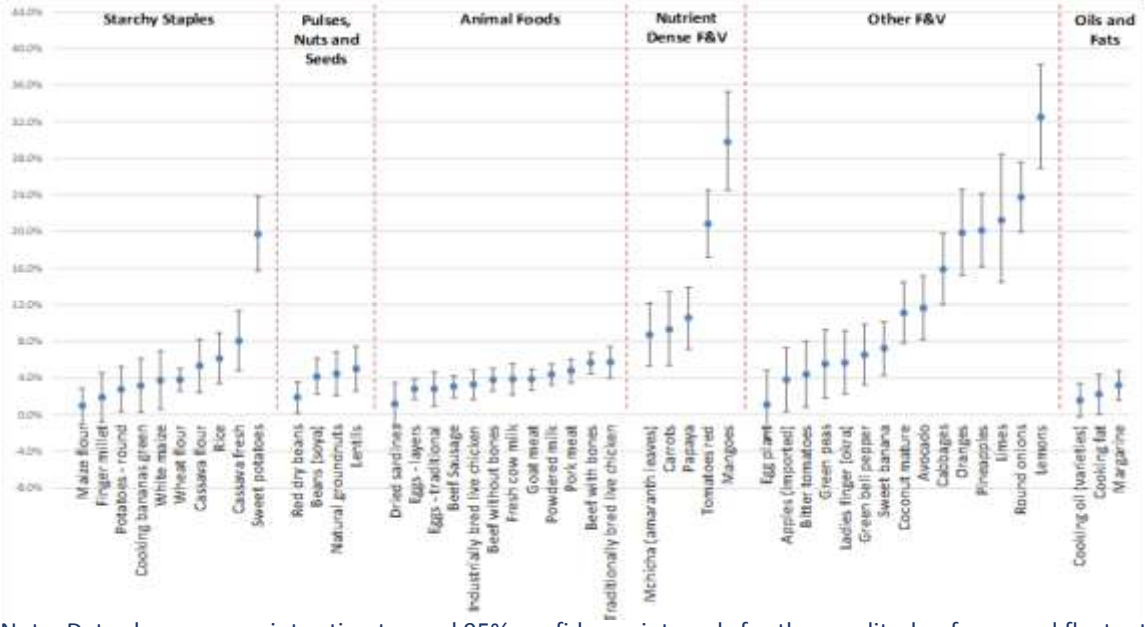
$$\text{min. } C_{kt} = \Sigma_i p_i q_i \text{ subject to } \Sigma_i n_{ij} q_i \geq EAR_i \text{ and } \Sigma_i n_{ie} q_i \geq E \qquad (2)$$

The objective is lowest diet cost given the price of each food (p_i), choosing quantities (q_i) to meet or exceed the population's estimated average requirement (EAR) for nutrient j given the quantity of each nutrient in each food n_{ij} , within the further constraint of energy balance for nutrient j=e at daily energy level E. From the Tanzania National Bureau of Statistics we have local prices for up to 49 food items at each of the 21 market locations every month, and use EAR values for each of 17 essential nutrients from the US Institute of Medicine for an adult woman, plus the quantity of nutrients in each food from the FAO's West African Food Composition Table supplemented by the USDA's National Nutrient Database.

Figure 1 provides national average results for equation (1), revealing that almost all foods have some degree of statistically significant seasonality over this 4-year period. The amplitude of that seasonality is

largest for fruits and vegetables, and also sweet potatoes which is classified here as a starchy staple. Seasonality is indistinguishable from zero for maize flour, dried fish, cooking oil and some other foods.

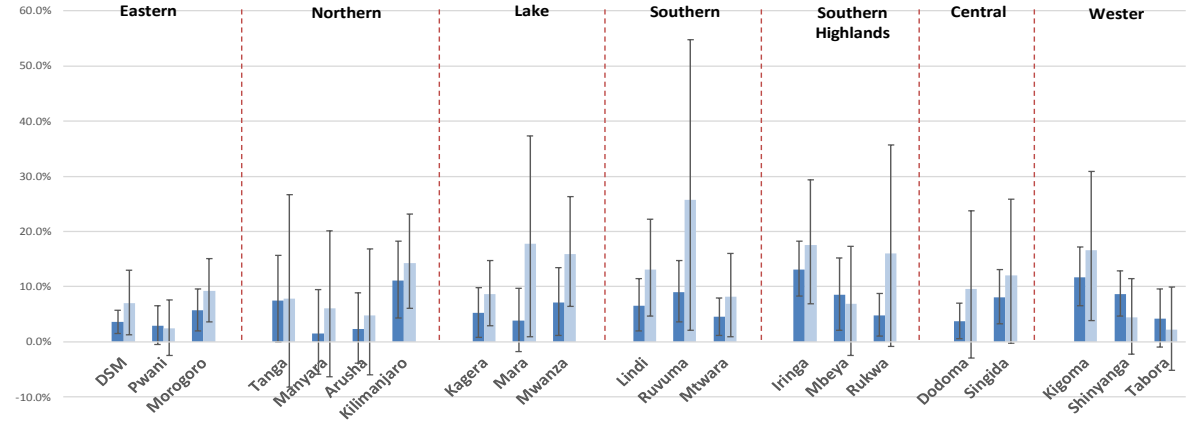
Figure 1. Seasonal variation in the cost of individual foods over all regions of Tanzania, 2011-15



Note: Data shown are point estimates and 95% confidence intervals for the amplitude of seasonal fluctuation in monthly price of each food shown at 21 market locations across Tanzania. Amplitude is shown as a percent of the average price at its lowest time of year.

Figure 2 shows results across regions, putting foods together in a least-cost diet through equation (1). Here the darker bars show seasonal variation in cost of nutrient adequacy including all micronutrients, while the lighter bars show seasonality in the cost of meeting only the calorie constraint. Seasonality is generally greatest at the most remote markets, and near zero in Dar es Salaam (DSM). The cost of calories has a larger seasonal amplitude than the least-cost diet, but much wider confidence intervals; the least-cost diet has significant seasonality in 15 of 21 markets, versus only 11 for the cost of calories.

Figure 2. Seasonal variation in the cost of nutrient adequacy and calorie adequacy by region, 2011-15

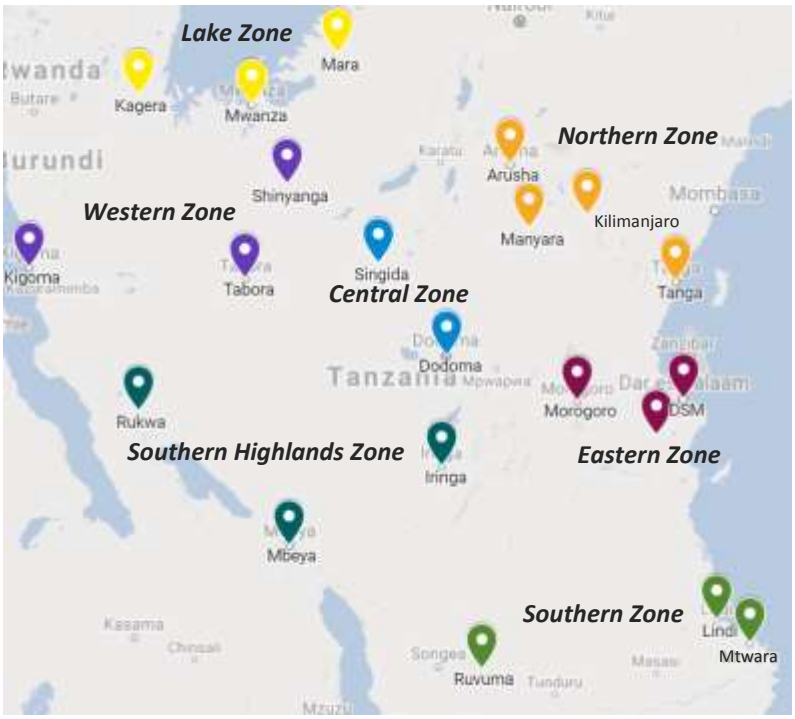


Note: As for Figure 1, but for a least-cost diet (dark bars) or lowest-cost source of calories at each market location.

In conclusion, this paper introduces a novel combination of techniques to measure seasonality in overall diet costs. We find high variation in the cost of meeting nutrient needs and also in the cost of calories, pointing to the need for continued market development to reduce seasonal insecurity.

ANNEX: Two self-explanatory figures that didn't fit:

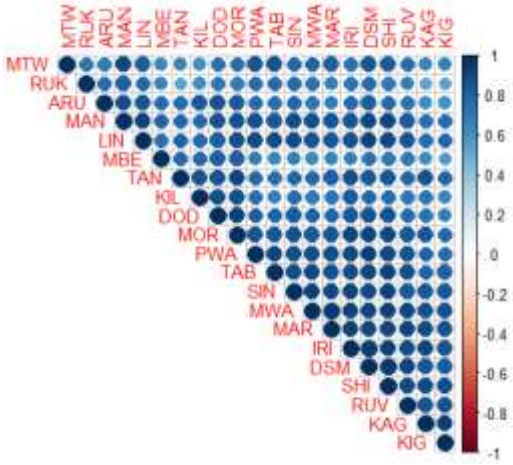
Map of 21 Regions and 7 Ecological Zones in Tanzania



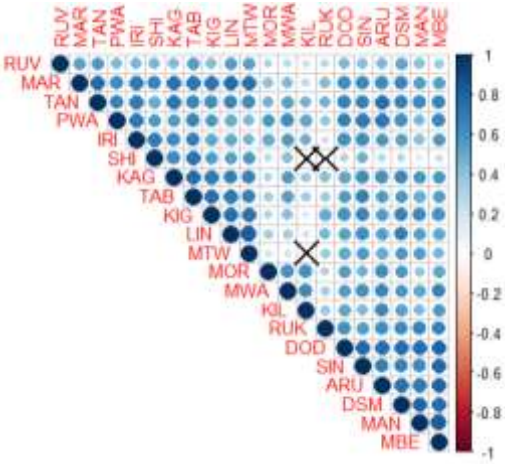
Note: the map is made by google via https://drive.google.com/open?id=1rKSXs-B6YTc5ewCOkUHMsiRsu-5jKsTm&usp=sharing

Spatial correlation in monthly food prices across 21 market locations in Tanzania, 2011-15

Panel A. Starchy staples (10 items)



Panel B. Nutrient-dense F&V (5 items)



Note: Darker blue indicates larger positive coefficient, X indicates zero. Location names abbreviated.