Seasonality in Food Prices and the Cost of a Nutritious Diet in Tanzania

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Motivation

Tanzania is among the world's poorest countries, whose population experiences severe deprivation including seasonal fluctuations in market prices and consumption of staple foods (Kaminski et al. 2016). Seasonality of food prices is widespread in Africa (Gilbert et al. 2017), and the resulting fluctuations in consumption have been linked to permanent deficits in health and human development (Christian and Dillon 2018).

Previous work has focused on seasonality in specific staples or in total food expenditure. Here we compare seasonality in the cost of calories to seasonality in the overall cost of a healthy diet, allowing for substitution between foods to meet nutrient needs (Masters et al. 2018). Measuring fluctuations in the affordability of nutrients beyond calories allows us to distinguish nutrition security from food security, identifying which foods contribute the most to seasonality in the cost of a nutritious diet.

Materials and Methods

The data used here are monthly prices for 46 distinct foods in local markets across 21 districts of Tanzania, observed from January 2011 through December 2015. Dara were collected by field agents for the National Bureau of Statistics, for the purpose of monitoring inflation, poverty rates and national income.

Our method employs market prices to compute the **Cost of Nutrient Adequacy (CoNA)** at each time and place, using linear programming to identify the least-cost combination of foods needed to meet nutrient needs for comparison with the cost of meeting only daily energy needs, which we call the **Cost of Caloric Adequacy (CoCA)**. This identifies the difference in seasonality between the cost of day-to-day survival with the cost of adequate nutrients for long-run health in terms of protein plus 7 essential minerals (Calcium, Iron, Magnesium, Phosphorus, Zinc, Copper, Selenium) and 9 essential vitamins (A, C, E, Thiamin, Riboflavin, Niacin, B-6, Folate, B-12). or each month and location we calculate:

Cost of Nutrient Adequacy (CoNA) $= minC_{kt} = min\Sigma p_i \times q_i,\ s.t.\ \Sigma n_{ij} \times q_i \geq EAR_j \text{ and } \Sigma n_{ie} \times q_i = E$ (1)

Cost of Caloric Adequacy (CoCA) $= minC_{kt} = min\Sigma p_i \times q_i,\ s.t.\ \Sigma n_{ie} \times q_i = E$ (2)

where n_{ij} is nutrient content in food i of nutrient j, for 46 foods and 17 nutrients; EAR_j is nutrient requirement of nutrient j, for an adult woman of reproductive age; and n_{ie} is energy content of food i, and E is daily energy needs of 2,000kcal per day.

To measure the seasonal component of month-to-month changes we use **harmonic (trigonometric) regression**:

Individual foods: $\ln(C_{ikt}) = \alpha_0 + \beta_s \sin(2\pi\omega t) + \beta_c \cos(2\pi\omega t) + \beta_t T(t) + \gamma_j Y_j + \theta_k R_k + e_{ikt}$ (3)

Diet-cost indexes: $I_{kt} = \alpha_0 + \beta_s \sin(2\pi\omega t) + \beta_c \cos(2\pi\omega t) + \beta_t T(t) + \gamma_j Y_j + \theta_k R_k + e_{kt}$ (4)

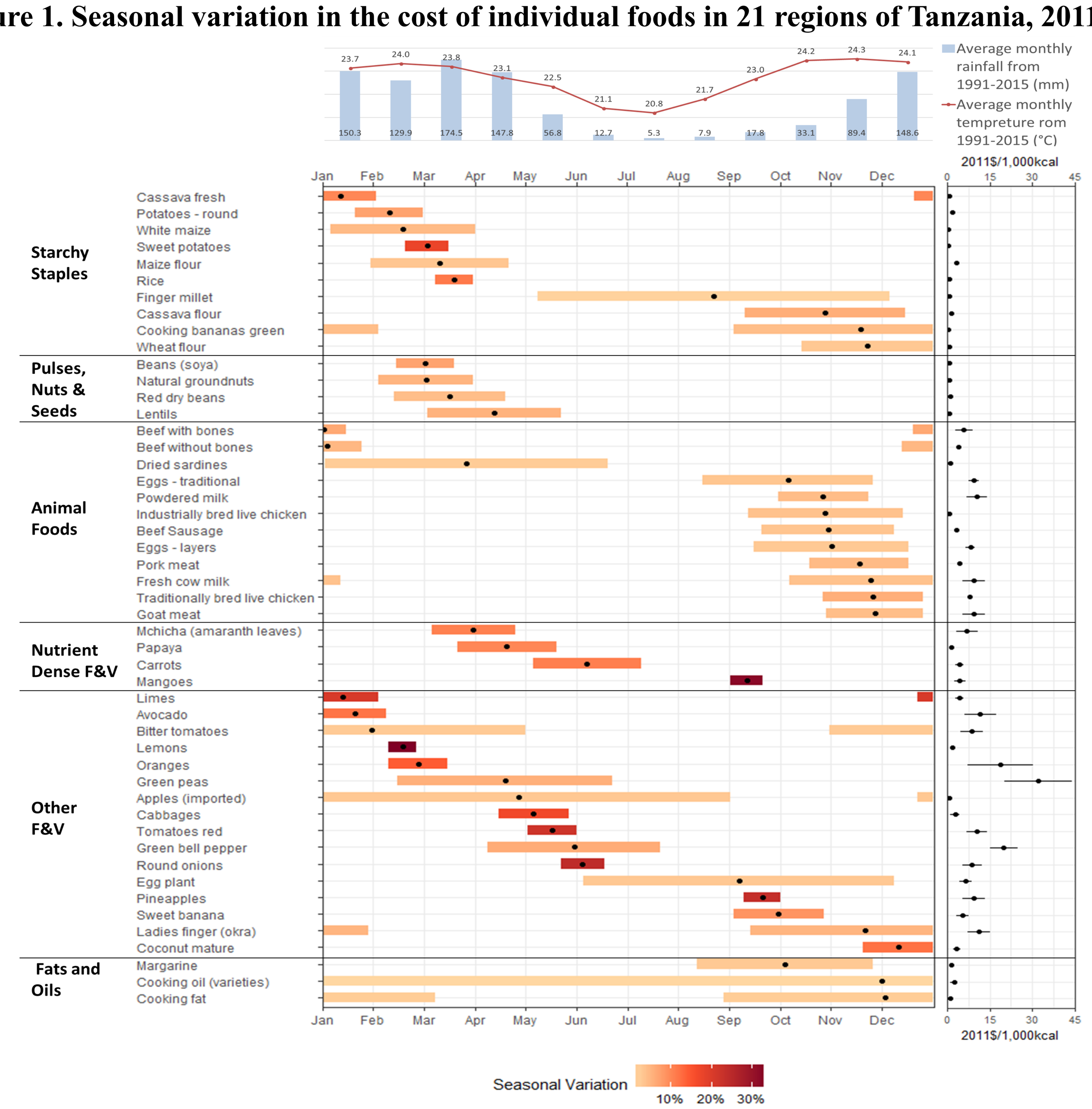
where C_{ikt} is the cost of food i in region k at time t in a monthly time series, I_{kt} is the indexes of CoNA and CoCA in region k at time t, ω is a constant equal to 1/12 indicating 12 months per annual cycle. β_s and β_c define the characteristics of seasonality, and β_t controls for quadratic time trends. Y_j and R_k are fixed effects for crop years and regions.

In the analysis, we focus on the **amplitude** and **peak timing** of seasonality as described in the results section (Naumova et al., 2007). Results by food and food group are shown in Figure 1, in the context of seasonality in rainfall and temperature that lead to the harmonic pattern shown in Figure 2. Regional variation within Tanzania is shown in Figure 3, and correlations between food groups and overall diet costs are shown in Figure 4.

Results

The food group with prices that have the sharpest seasonality is fruits and vegetables (F&V), whose prices peak just before harvest at the start of the dry season.

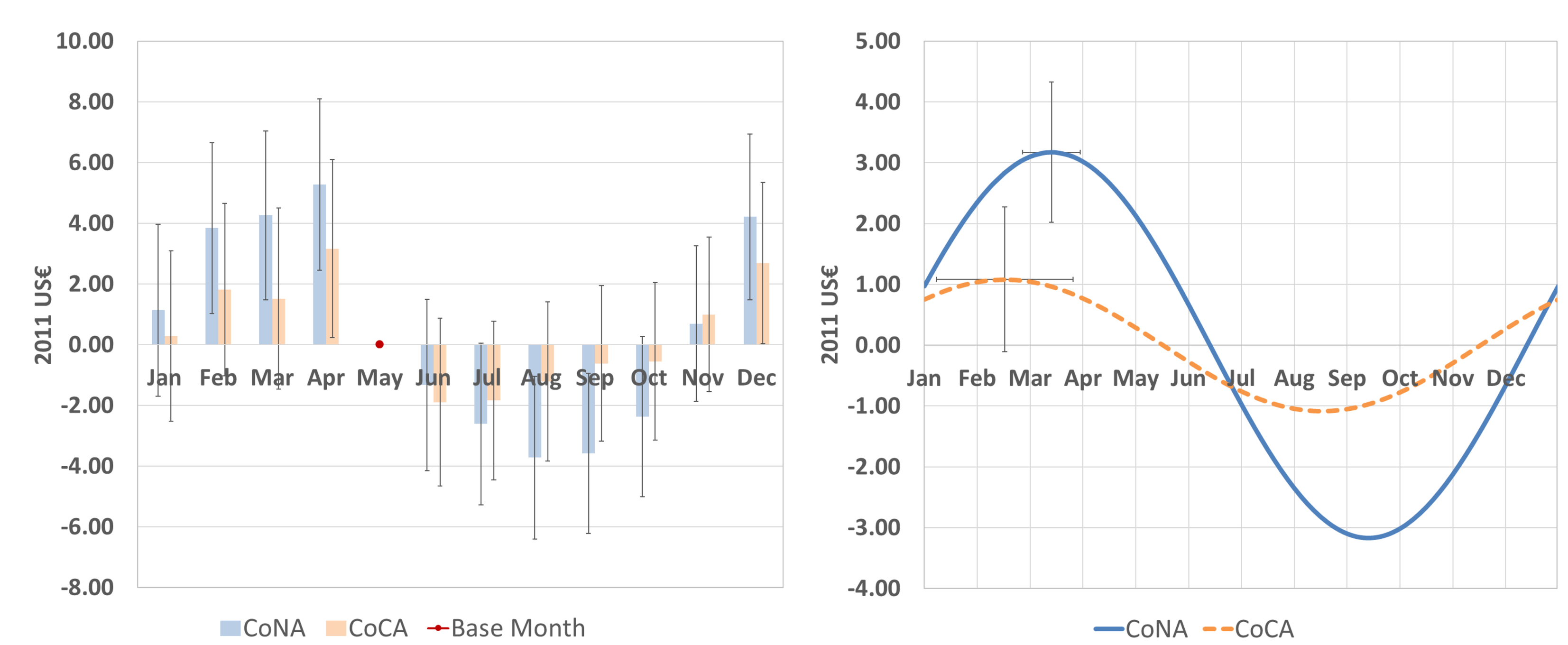
Figure 1. Seasonal variation in the cost of individual foods in 21 regions of Tanzania, 2011-15



Note: Data shown are 95% confidence intervals around the peak month, in darker colors for higher levels of seasonal variation, based the price of each food item at local markets in 21 regions of Tanzania. Seasonality is not significantly different from zero for finger millet, white maize, dried sardines, eggplants, apples (imported), bitter tomatoes, cooking oil and cooking fat. (8 of 46 food items). Also shown is average monthly rainfall and temperature (top panel), and average price and its standard deviation for each food.

For overall diet costs there is significant seasonality in the Cost of Nutrient Adequacy (CoNA), but not in the Cost of Calorie Adequacy (CoCA).

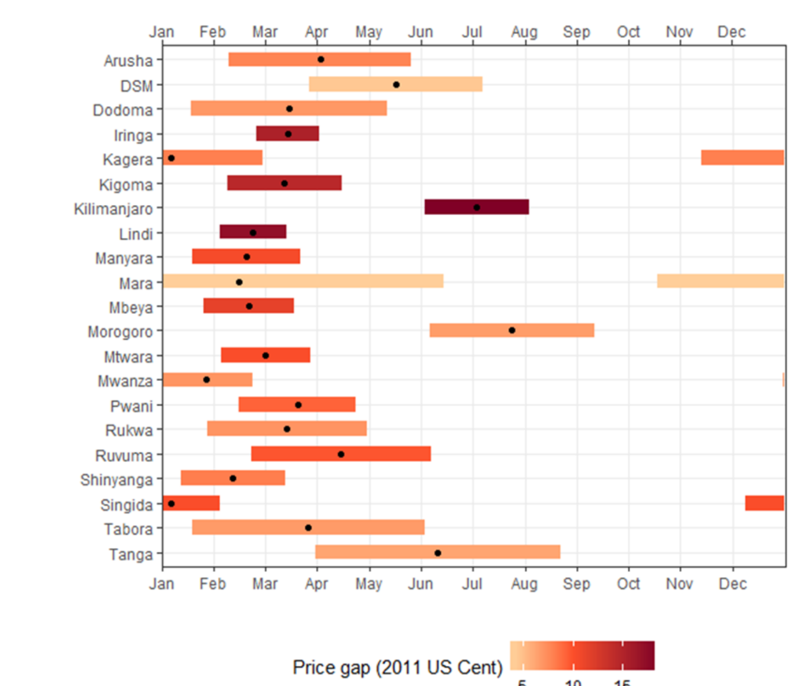
Figure 2. Seasonal variation of Cost of Nutrient Adequacy (CoNA) and Cost of Calorie Adequacy (CoCA) over 21 regions in Tanzania, 2011-15



Note: Data shown are 95% confidence intervals for each month (left panel) and for the harmonic regression (right panel). Seasonal variation in CoNA shown using blue bars and the solid blue line is significant, while variation in CoCA shown using orange bars and the dashed orange line is not significantly different from zero (p=0.05).

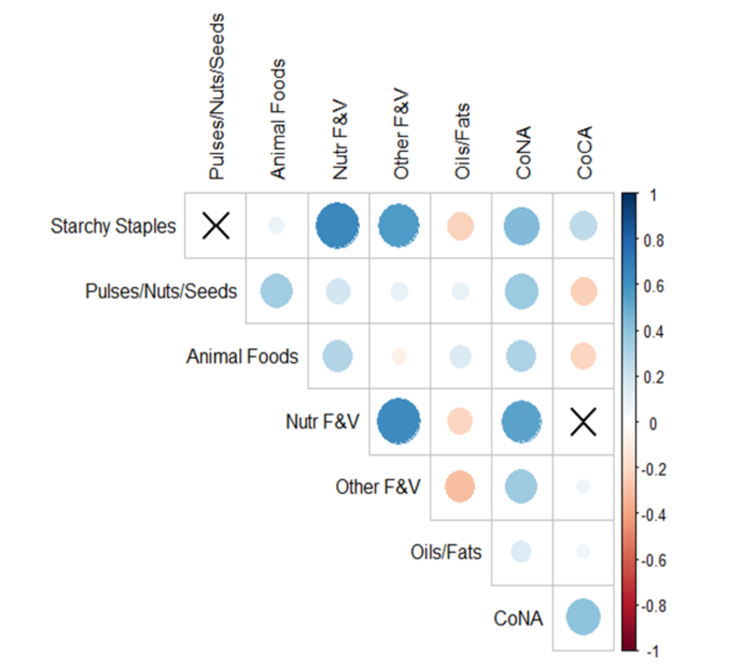
Results (cont'd)

Figure 3. Seasonal variation of CoNA in each region of Tanzania, 2011-15



Note: Data shown are 95% confidence intervals around the peak month, in darker colors for higher levels of seasonal variation. Seasonality is not significantly different from zero for Dodoma, Mara and Arusha (3 of 21 regions).

Figure 4. Correlation between CoNA, CoCA and prices of individual food groups, 2011-15



Note: Blue circles indicate positive correlations between prices of the two food groups or indexes, and red circles indicate negative correlations, and an X indicates no significant correlation at p=0.05. Darker, larger circles indicate greater magnitude of the correlation. Nutr F&V are Nutrient-rich Fruits and Vegetables.

Conclusions

This paper uses a novel combination of techniques to measure seasonality in a comprehensive list of food items and overall diet costs in Tanzania, with three important findings:

- Most food items display significant seasonality in retail prices. Fruits and vegetables (F&V) have the most extreme seasonality, with different seasonal peaks according to the harvest timing;
- The least-cost combination of foods needed to reach nutrient adequacy has significant seasonality, while the cost of calories as such fluctuates less predictably. Most regions within Tanzania face their peak cost of nutrient adequacy towards the end of the rainy season in March/April, but a few regions like Kilimanjaro have later peaks;
- Each region's cost of nutritious diets is highly correlated with seasonality in prices of its nutrient dense F&V. This suggests a need for more targeted investments in market infrastructure for storage and transport of those foods among markets over time to lower and smooth the cost of healthier diets, alongside continued investments to meet daily energy needs in places with high food insecurity.

This finding is specific to the type of prices used, which are collected at the principal food markets in each region. Seasonal scarcity at even more remote locations is likely to be even more severe, for which additional data on local prices would be needed.

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