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.

We employ these prices to compute the **Cost of Nutrient Adequacy (CoNA)**, using linear programming to identify the combination of foods needed to meet nutrient needs with the lowest total expenditure at each time and place, for comparison with the cost of meeting only daily energy needs, which we call the **Cost of Calorie 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).

For each month and location we calculate:

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

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

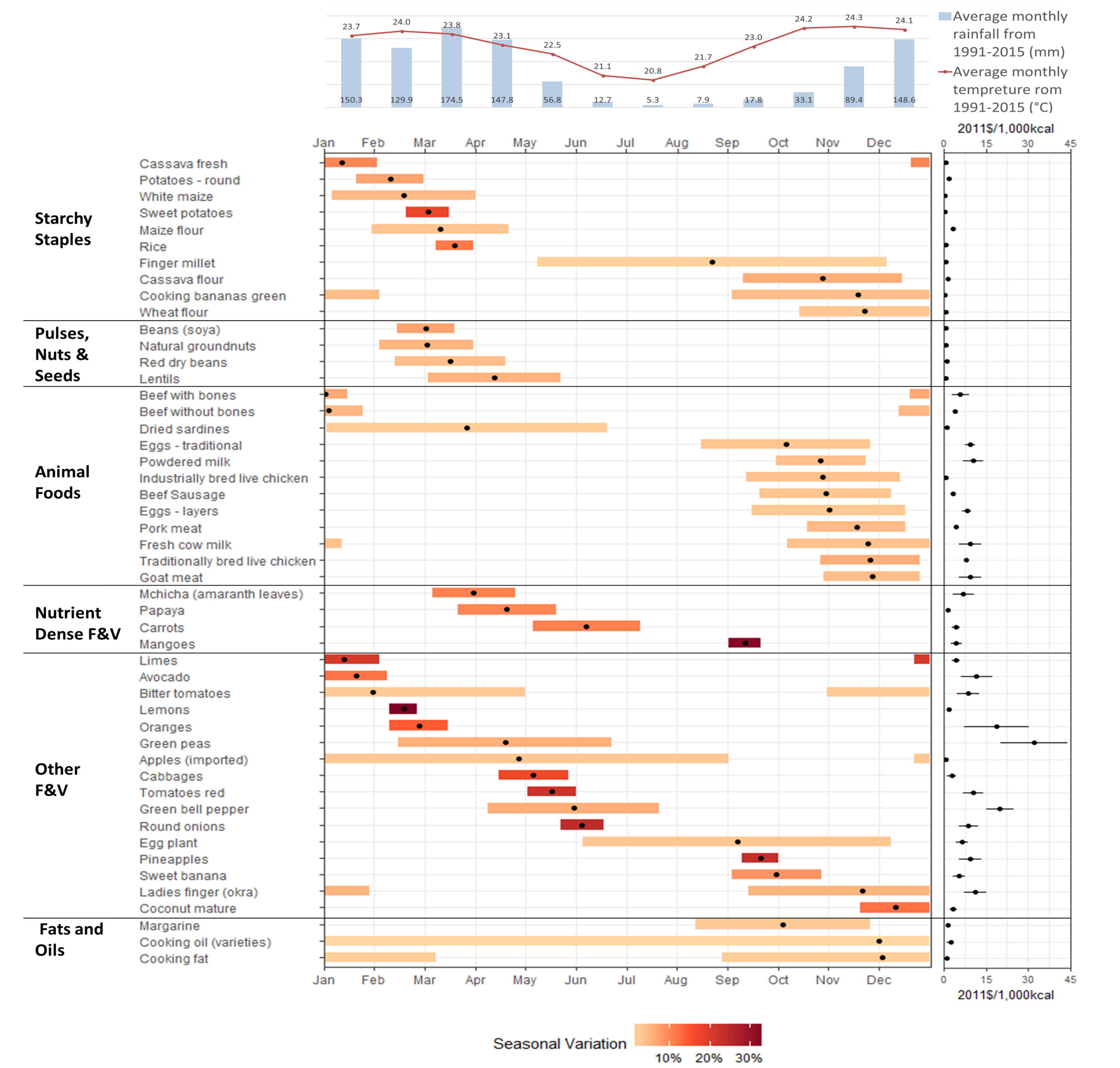
where C_{ikt} is the cost of food i in region k at time t in a monthly time series, I_{kt} is the indexes of CoNA and CoCA in region k at time t, ω is a constant equal to 1/12 indicating 12 months per annual cycle. β_s and β_c define the characteristics of seasonality, and β_t controls for quadratic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

The food group whose prices have the sharpest seasonality is fruits and vegetables (F&V), whose prices peak just before harvest at the start of the dry season. They also have the highest food prices in 2011$/1,000kcal comparing to other food groups in general.

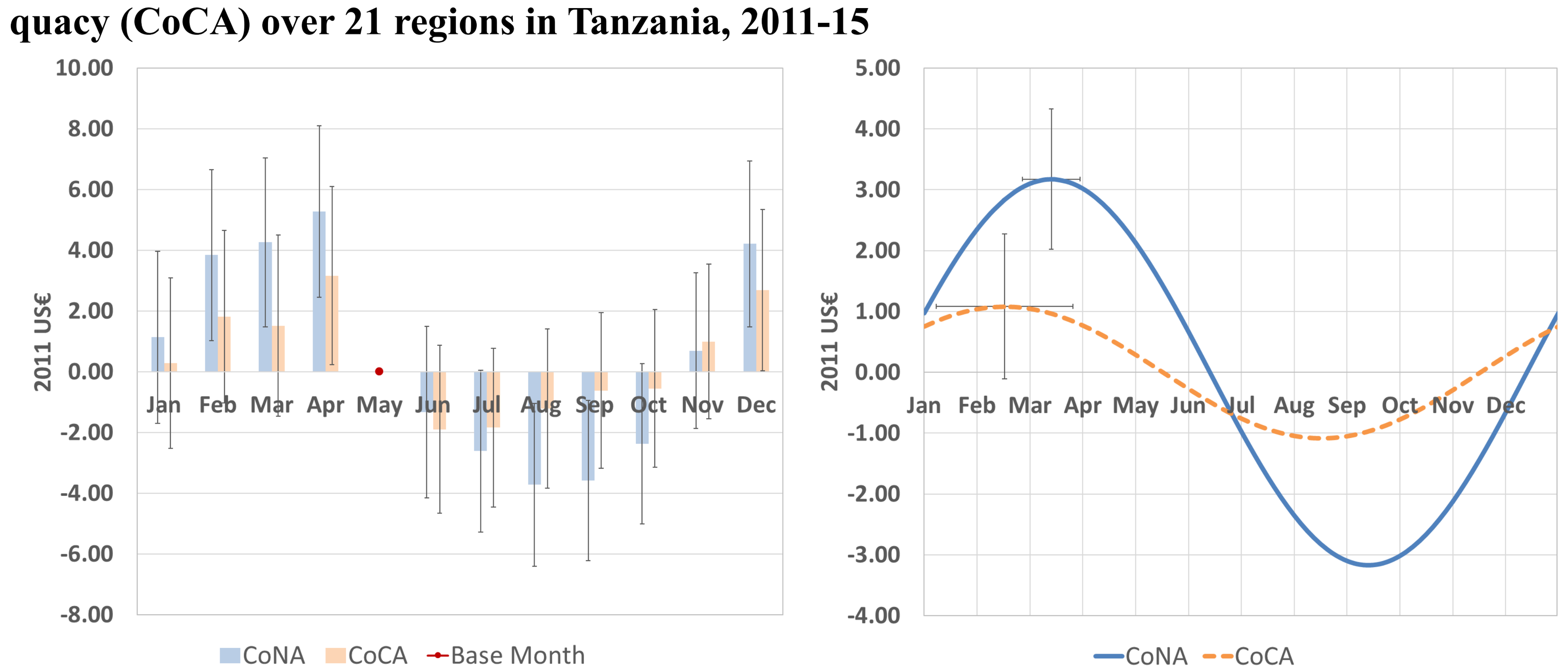
Figure 1. Seasonal variation in the cost of individual foods in 21 regions of Tanzania, 2011-15



Note: data shown are 95% confidence intervals as bars for the peak timing. The color gradation shows the estimated seasonal variation in monthly price of each food item at 21 market locations across the nation. The side graph on the top shows the average monthly rainfall between 1991 and 2005, and the side graph to the right displays the average monthly price per 1,000kcal and the standard deviation of each food item. The seasonal variations for 8 food items were not significant, including finger millet, white maize, dried sardines, egg plants, apples (imported), bitter tomatoes and cooking oil (varieties) and cooking fat.

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

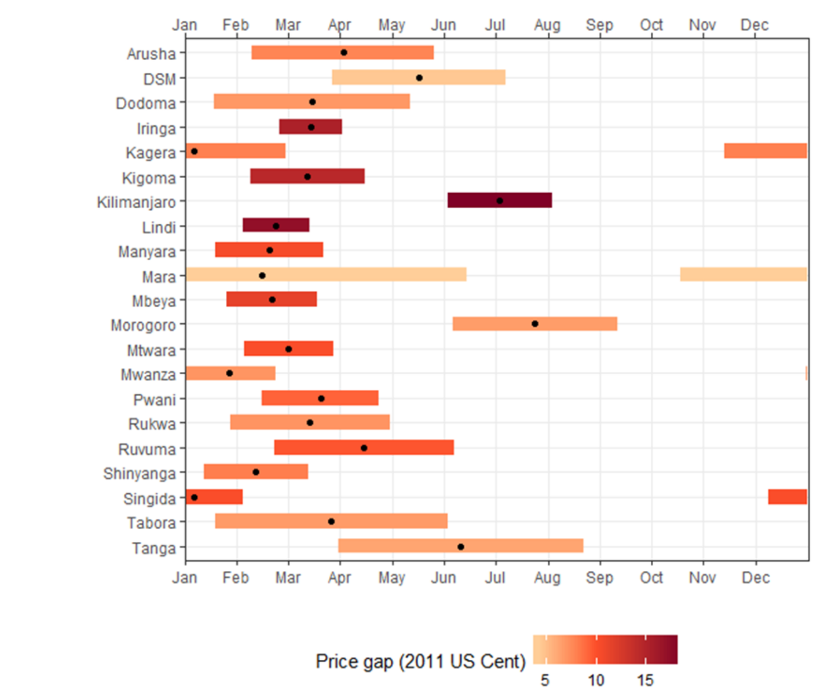
Figure 2. Seasonal variation of Cost of Nutrient Adequacy (CoNA) and Cost of Calorie Adequacy (CoCA) over 21 regions in Tanzania, 2011-15



Note: error bars show 95% confidence intervals of the relevant estimates. At a significance level of 5%, dash line indicates that the seasonality of CoCA is not significant, while solid line indicates that the seasonality of CoNA is significant.

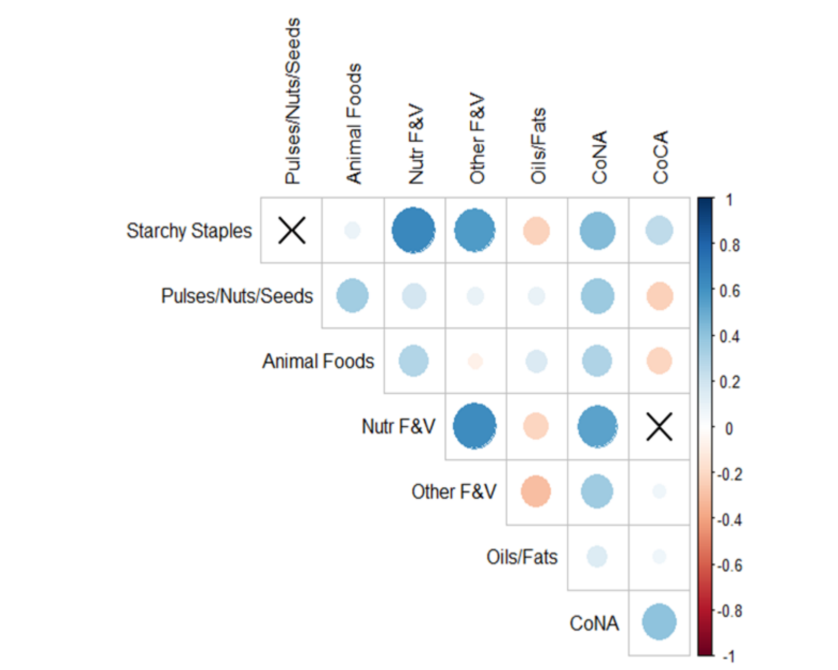
Results (cont'd)

Figure 3. Seasonal variation of 21 Regional CoNA indexes, 2011-15



Note: data shown are 95% confidence intervals as bars for the peak timing. The color gradation shows the estimated seasonal variation in the regional CoNA indexes. The seasonal variations for 3 regions were not significant, including Dodoma, Mara and Arusha.

Figure 4. Correlation Coefficient of Regional Prices among 6 Food Groups and CoNA



Note: Nutr F&V is the abbreviation of Nutrient-rich Fruits and Vegetables. Other F&V is the abbreviation of Other Fruits and Vegetables. CoNA and CoCA are the indexes representing the cost of nutrient adequacy and the cost of calorie adequacy. Blue circles indicate the prices of the two food groups or indexes on horizontal and vertical directions are positively correlated, red circles indicates that they are negatively correlated at the significance level of 0.05. Nonsignificant correlation is shown as an "X" symbol in the figure.

Conclusions

This paper use 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;
- Even allowing people to substitute freely among foods as prices vary, the lowest possible expenditure needed to meet all nutrient needs, or CoNA, has significant seasonality, while the cost of calories as such fluctuates less predictably. Most regions within Tanzania face their peak CoNA 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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