Impacts of Agricultural and Trade Policy on the Cost of Nutritious Diets in Ghana and Tanzania

AERC Framework Paper*

Yan Bai, William A. Masters, Fulgence J. Mishili, Daniel B. Sarpong**
This version revised 9 October 2019

Abstract (250 words)
Policies and programs can improve nutrition through systemic change, making healthier diets more affordable at all times and places. This study compares two kinds of intervention, increased agricultural productivity to lower prices, and better marketing enhancements that lower transport and storage costs, across four categories of food: starchy staples, leguminous grains, fruits and vegetables, and animal foods. We estimate, using linear programming techniques, the monthly Cost of Nutrient Adequacy (CoNA) using these food groups. The paper traces impacts from each kind of the two interventions to the overall cost of meeting estimated average requirements for 17 essential nutrients each month over five years in 10 regions of Ghana and 21 regions of Tanzania through the CoNA. Interventions targeting food production such as Ghana's Planting for Food and Jobs Program that mainly aims to raise harvest quantities and primarily serve to alter the average price level for each food group, and efforts to improve transport and storage, such as market infrastructure for Tanzania's National Trade Policy that alter transaction costs and hence the standard deviation of prices between locations and time periods, are simulated. The simulations suggest that for Ghana, the overall cost of nutritious diets is most sensitive to improvements in fruit and vegetable prices, whereas for Tanzania sensitivity is greatest for the level of leguminous grain prices as well as variation in fruit and vegetable prices. Results point to opportunities for more investment targeting, but diet costs remain sensitive to the prices of starchy staples and animal products. Measuring impacts on the overall cost of meeting all nutrient needs shows the importance of a balanced approach, targeting low and stable prices for all major food groups.

* This paper was prepared under AERC grant RC17535, as part of a collaborative research project on Agricultural and Food Policy Analysis for Nutrition Outcomes in Africa funded by the Bill & Melinda Gates Foundation, building on methods developed in a project on Changing Access to Nutritious Diets in Africa and South Asia (CANDASA), funded by UKAid and the Bill & Melinda Gates Foundation. The authors are grateful to Wilson Wasike and Witness Simbanegavi for their leadership of the project, and to workshop participants in Addis Ababa (28-29 June 2018) and Nairobi (28-30 November 2018) for valuable feedback.

** Contact author:
Daniel B. Sarpong
Dean, School of Agriculture
Assoc. Prof, Department of Agricultural Economics & Agribusiness
University of Ghana
Email: dbsarpong@ug.edu.gh /akwei7@yahoo.com, Phone: +233-244-737745

1. Introduction and motivation

This study compares the impacts of alternative agricultural development strategies on the affordability of nutritious diets in Ghana and Tanzania. Policy outcomes are measured by the cost of the most affordable basket of foods at each market every month that meets an average adult woman's estimated average requirements for 17 essential nutrients (protein, calcium, iron, magnesium, phosphorus, zinc, vitamin-C, thiamin, riboflavin, niacin, vitamin-B6, folate, vitamin-B12, vitamin-A, vitamin-E, copper, and selenium), based on policy-induced changes in the distribution of prices for 42 different foods in Ghana and 46 in Tanzania, observed monthly over five years at local markets in 10 regions of Ghana and 21 regions of Tanzania. Our approach is based on the classic FAO (1996) definition of food security, "when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life." By comparing market prices across regions and over time, we capture variation in physical and economic access across people, using a whole-of-diet approach that adds up the cost of foods needed to meet all essential nutrient requirements.

2. Policy options

How do agricultural production and market policies affect the affordability of nutritious diets? To compare different kinds of policy interventions, we divide the list of all foods into four groups, each meeting different kinds of nutritional needs, and each requiring different kinds of agricultural inputs. The four groups are starchy staples (cereal grains, starchy roots and plantains), leguminous grains (pulses, nuts and seeds), animal products (including fish), and fruits and vegetables. The first three groups are traditional targets for international and national agricultural services as well as marketing and trade initiatives, while fruits and vegetables have received less attention from the public sector. The paper then divides policy or program interventions into productivity enhancements that are assumed to lower average prices at each market every month, and transport or storage improvements that are assumed to reduce marketing margins over time and space and hence reduce the standard deviation of prices between markets and from month to month.

This categorization of policies between productivity changes that lower market prices versus marketing improvements that reduce price variation is designed to compare and contrast the broad lines of major recent policy initiatives in Ghana and Tanzania, each of which reflects similar efforts under way in other countries. Ghana's *Planting for Food and Jobs (PFJ)* program was launched in 2017 as a national plan to increase food production in all 216 districts of the country. The program focuses on "motivating farmers to adopt certified seeds and fertilizers through a private sector led marketing framework, by raising the incentives and complimentary service provisions on the usage of inputs, good agronomic practices, marketing of outputs over an e-Agriculture platform". The program targets only the most widely marketed crops (maize, rice, sorghum, soya bean, tomato, chili peppers and onions), and does not aim to enhance consumer access to vegetables or most nutrient-dense fruits and vegetables. This contrasts with Tanzania's *National Trade Policy* launched in 2003, which has led to a number of initiatives aimed at developing better market linkages around the country for transport and storage of many different products.

3. Research method

Our analytical framework uses linear programming to calculate least-cost diets, meaning the combination of locally available foods needed to meet nutrient requirements for an active and health life. Soon after the nutrient requirements were first discovered, Stigler (1945) developed mathematical tools to calculate least-cost diets. The method has been widely used since to determine the cost of subsistence (O'Brien-Place and Tomek, 1983; Chastre et al. 2007; Omiat and Shively, 2017; Allen, 2017; Hirvonen et al. 2019) and to make dietary recommendations suitable for low-income people such as the United States Department of Agriculture's "Minimum-Cost Food Plan" developed for people facing extreme poverty during the depression of the 1930s (Cofer et al. 1962). It has also been used internationally, for example, to make recommendations in Denmark (Parlesak *et al.*, 2016) and the Netherlands (Gerdessen and de Vries, 2015). One of the most important uses for least-cost diets is to help nutrition assistance programs meet specific needs of children and other vulnerable groups, as in the Cost-of-the-Diet approach developed by Save the Children UK and others (Chastre *et al.* 2007, Deptford *et al.* 2017, Akhter *et al.* 2018), and Optifood developed by the London School of Hygiene and Tropical Medicine and others (*Optifood* 2012, Vossenaar *et al.* 2017).

In this Framework Paper, following Masters *et al.*, (2018), we compute this lowest possible Cost of Nutrient Adequacy (CoNA) using monthly national average food prices, based on the minimum cost of meeting recommended daily intakes of 17 essential nutrients and energy. CoNA is defined as the solution to:

$$\text{min. } C_{kt} = \Sigma_i p_i q_i \text{ subject to } \Sigma_i n_{ij} q_i \geq EAR_i \text{ and } \Sigma_i n_{ie} q_i = E \quad (1)$$

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 of 2,000kcal. Variation in CoNA comes from variation in prices, as measured for a market information system (Ghana's MoFA-SRID) or inflation statistics (Tanzania National Bureau of Statistics). To compute the price indexes, the price of each food was converted from reported units, such as price per dozen eggs, to cost per unit of weight and/or of dietary energy of the edible portion, and then converted to a common currency and adjusted for inflation by purchasing-power-parity (PPP) conversion factor provided by the World Bank (2016).

As CoNA is the sum of the costs of a package of different food items which may vary over time depending on the price structure and foods' nutritional attributes, it has a usually non-linear relationship with food prices. Therefore, the food price variations introduced by any agriculture, trade and nutrition policies may have different scales of impact on the cost of nutrient adequacy, or the CoNA.

In this framework paper, we consider only policies that are national in scope, dividing interventions into those that affect production levels and hence average food prices, and those that affect transport or storage and hence food price differences over space and time. The agriculture and trade policy scenarios for Ghana and Tanzania simulate interventions that affect production levels and hence average food prices (Schneider and Gugerty, 2011; Fuglie and Rada, 2013) as for Ghana, and those that affect transport or storage (Regolo, Portugal-Perez and Brenton, 2014) and hence food price differences over space and time as for Tanzania. Tanzania's National Trade Policy efforts are to improve transport and storage such as better market infrastructure aimed at developing market linkages around the country for transport and storage

of many different products. Regolo, Portugal-Perez and Brenton (2014) indicate such trade policy efforts have relatively led to good domestic trade integration of Tanzania. For Ghana, her Planting for Food and Jobs (PFJ) program is supply driven to raise harvest quantities and primarily serve to alter the average price level for each food group. Mabe, Ehiakpor and Danso-Abbeam (2018) in assessing the PFJ, a year after implementation, indicated maize, rice and soyabean yields under the PFJ participants increased by 3.66%, 8.54% and 7.54% in that order, and the programme increased fertilizer application rates. Increased agricultural output can change the relative prices of domestically traded goods. The basic idea is that improving agricultural production (higher productivity and improved yields) mostly lowers the national food price level (and hence average prices across markets) and improving food market functioning mostly lowers food price differences (and hence their standard deviation). In specific terms, we are modeling high-level agricultural and food policies for nutrition outcomes (AFPON) purposes, based on what Ghana and Tanzania have been doing. We also divide interventions by the type of food that is targeted, differentiating between starchy staples, leguminous grains, animal products or fruits and vegetables.

In this paper, we simulate the distributions of monthly CoNA in Ghana and Tanzania given these two kinds of price variations in distinct food categories. The first kind of variation is that the food prices of distinct food categories changes by 10% and the standard deviation remains the same, which can be a result from changes on higher agricultural productivity, consumers' demand, taxes or tariffs, and/or trading costs. The second kind of variation is to double or halve the standard deviation of prices over time of food items in distinct food categories and keep mean values of such food items the same (better markets), as an effect of changes on food market efficiency due to improved/worsened transportation and storage.

4. Data sources

From Ghana Statistical Service (GSS), and Tanzania's National Bureau of Statistics (NBS), we have national average monthly prices for 42 and 46 food items in these two countries. Prices for each item are unweighted averages over a variety of retail markets, covering all 10 regions of Ghana and all 21 regions of mainland Tanzania.

We 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. Based on the food groups defined by the Minimum Dietary Diversity for Women (MDD-W) indicator, we regroup the food items into 4 mutually exclusive food categories, which are Starchy Staples, Pulses/Nuts/Seeds, Animal Foods and Fruits/Vegetables.

5. Results

Using foods' energy density data, we calculate the food prices in 2011USD per 1,000 kcal of dietary energy as summarized in Tables 1 and 2. For Ghana, we have a total of 60 monthly observations from January 2012 to December 2016 for 42 items. Of these, 15 food items are in the starchy staple group, reflecting the strong focus of data collection efforts on that category. The average price of each item per 1,000 kcal ranges widely, from $0.25 for cowpeas to $104.83 for cocoyam leaves. In Ghana, prices of fruits and vegetables (in PPP USD) are relatively high. The volatility of food prices over time, as represented by Coefficient of Variation (CV), varies widely from 0.04 for beef to 0.18 for fresh cassava and local rice.

Table 1. Monthly Food Prices in Ghana, January 2012 - December 2016 (2011$/1,000 kcal)[1]

Food Groups	No	Foodstuffs	Obs.	Mean	Std. Dev.	CV	Min	Max
Starchy Staples	1	Cassava (fresh)	60	1.32	0.24	0.18	0.76	1.71
	2	Gari[2]	60	3.79	0.39	0.10	3.32	4.50
	3	Kokonte[2]	60	2.38	0.23	0.09	2.08	2.83
	4	Cassava dough	60	1.70	0.27	0.16	1.31	2.16
	5	Cocoyam	60	1.70	0.27	0.16	1.31	2.30
	6	Sorghum	60	0.44	0.02	0.05	0.39	0.48
	7	Maize	60	0.29	0.04	0.15	0.23	0.37
	8	Maize, ground	60	0.45	0.06	0.12	0.38	0.56
	9	Millet	60	0.46	0.04	0.08	0.40	0.53
	10	Plantain (green)	60	3.39	0.49	0.15	2.82	4.26
	11	Rice (imported)	60	1.34	0.09	0.07	1.21	1.52
	12	Rice (local)	60	0.62	0.11	0.18	0.49	0.80
	13	Wheat Flour	60	0.77	0.06	0.08	0.69	0.88
	14	White Oats	60	1.90	0.18	0.09	1.68	2.27
	15	Yam	60	1.25	0.18	0.15	0.98	1.55
Pulses, Nuts & Seeds	16	Groundnuts	60	1.74	0.25	0.15	1.46	2.24
	17	Cowpeas	60	0.25	0.02	0.08	0.22	0.29

Animal Foods	18	Beef with bones	60	5.04	0.21	0.04	4.64	5.48
	19	Chicken Eggs	60	47.80	5.14	0.11	39.70	57.45
	20	Corned Beef	60	1.83	0.18	0.10	1.59	2.28
	21	Dried fish	60	12.76	1.25	0.10	11.12	15.29
	22	Evaporated Milk	60	11.02	0.81	0.07	9.97	12.56
	23	Frozen chicken	60	5.31	0.47	0.09	4.49	6.34
	24	Goat (fresh)	60	19.55	1.30	0.07	16.84	21.96
	25	Guinea fowl	60	7.26	0.37	0.05	6.74	7.94
	26	Herrings (smoked)	60	8.52	0.67	0.08	7.50	9.75
	27	Live chicken	60	18.71	1.22	0.07	16.81	22.65
	28	Mutton (fresh)	60	5.23	0.40	0.08	4.64	6.04
	29	Pork	60	6.33	0.41	0.07	5.76	7.36
	30	Snails	60	20.74	1.54	0.07	18.58	23.82
	31	Bushmeat	60	7.49	0.50	0.07	6.83	8.46
Fruits and Vegetables	32	Apples	60	1.28	0.09	0.07	1.14	1.43
	33	Banana	60	3.16	0.20	0.06	2.75	3.53
	34	Coconut	60	1.94	0.24	0.12	1.69	2.40
	35	Cocoyam leaves	60	104.83	10.95	0.10	92.28	141.19
	36	Eggplants	60	17.70	2.25	0.13	14.25	22.05
	37	Mango	60	8.02	0.88	0.11	6.88	10.02
	38	Okra	60	9.29	1.24	0.13	7.13	11.45
	39	Onions	60	33.13	3.73	0.11	28.14	40.84
	40	Oranges	60	4.73	0.56	0.12	4.08	5.86
	41	Pineapple	60	11.46	1.73	0.15	9.07	14.18
	42	Tomatoes	60	15.06	2.33	0.15	11.59	19.21

Note:

1. Authors' calculations from Ghana Statistical Service (GSS) data
2. Processed cassava products.

For Tanzania, we have 60 monthly observations over 5 years from January 2011 to December 2015 for 46 items spanning 10 food groups as the final database for index calculation. Starchy staples group, as the largest food group in terms of the number of food items, contains 10 items in our dataset. Average prices per 1,000 kcal range from $0.31 for white maize to $24.78 for green peas, and prices per kg range from $1.11 for white maize to $39.56 for powered milk. The volatility of prices ranges from a CV of 0.02 for beef sausage and goat meat to 0.18 for limes.

Table 2. Monthly Food Prices in Tanzania, January 2011 - December 2015 (2011$/1,000 kcal)

Food Group	No	Foodstuff	Obs.	Mean	Std. Dev.	CV	Min	Max
Starchy Staples	1	Cassava (dried flour)	60	0.60	0.07	0.11	0.48	0.79
	2	Cassava fresh	60	0.77	0.07	0.09	0.60	0.90
	3	Plantain	60	1.64	0.09	0.05	1.45	1.90

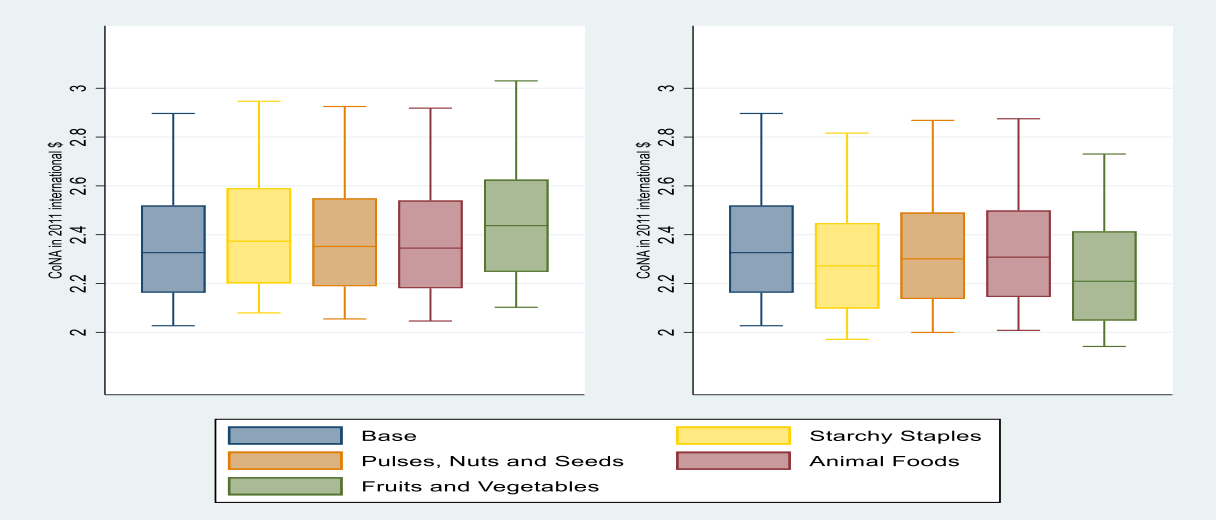
	4	Finger millet	60	0.68	0.11	0.17	0.50	0.87
	5	Maize flour	60	0.47	0.06	0.12	0.37	0.63
	6	Potatoes – round	60	2.25	0.13	0.06	1.97	2.63
	7	Rice	60	0.74	0.12	0.16	0.57	0.98
	8	Sweet potatoes	60	1.70	0.14	0.08	1.46	1.97
	9	Wheat flour	60	0.62	0.04	0.06	0.56	0.71
	10	Maize (white)	60	0.31	0.04	0.12	0.24	0.41
Pulses, Nuts & Seeds	11	Soybeans	60	0.65	0.03	0.04	0.59	0.70
	12	Lentils	60	1.28	0.12	0.09	1.08	1.48
	13	Beans (red)	60	0.78	0.04	0.05	0.72	0.87
	14	Groundnuts	60	0.66	0.05	0.08	0.58	0.78
Animal Foods	15	Milk (fresh)	60	2.89	0.16	0.05	2.38	3.07
	16	Milk (powdered)	60	7.99	0.38	0.05	7.02	8.72
	17	Beef sausage	60	4.32	0.08	0.02	4.18	4.54
	18	Beef with bones	60	3.92	0.19	0.05	3.47	4.43
	19	Beef without bones	60	1.11	0.04	0.04	1.01	1.26
	20	Sardines (dried)	60	5.99	0.46	0.08	5.12	6.91
	21	Goat meat	60	9.51	0.38	0.04	8.37	10.19
	22	Chicken (live, industrial)	60	6.57	0.31	0.05	5.6	6.99
	23	Pork meat	60	3.17	0.28	0.09	2.45	3.63
	24	Chicken (live, traditional)	60	11.9	0.79	0.07	9.94	13.26
	25	Eggs (layers)	60	8.42	0.28	0.03	7.89	8.88
	26	Eggs (traditional)	60	11.81	0.69	0.06	10.3	12.66
Fruits and Vegetables	27	Amaranth leaves (mchicha)	60	5.74	0.57	0.10	4.85	6.81
	28	Carrots	60	7.05	0.69	0.10	6.01	9.08
	29	Mangoes	60	4.46	0.63	0.14	2.97	6.06
	30	Papaya	60	5.63	0.50	0.09	4.71	6.64
	31	Tomatoes (bitter)	60	8.86	0.46	0.05	7.85	10.72
	32	Eggplant	60	9.44	0.49	0.05	8.47	10.83
	33	Cabbages	60	2.80	0.27	0.10	2.30	3.48
	34	Green peas	60	24.78	1.74	0.07	20.72	28.40
	35	Green bell pepper	60	16.46	0.92	0.06	14.78	19.16
	36	Okra	60	11.28	0.75	0.07	9.97	13.25
	37	Onions	60	6.43	0.77	0.12	5.21	8.86
	38	Tomatoes (red)	60	10.44	1.19	0.11	8.36	13.53
	39	Apples (imported)	60	19.58	1.62	0.08	15.85	23.62
	40	Avocado	60	1.91	0.12	0.06	1.67	2.18
	41	Coconut (mature)	60	5.52	0.51	0.09	4.78	6.85
	42	Lemons	60	11.75	2.03	0.17	8.26	17.99
	43	Limes	60	15.62	2.87	0.18	12.00	23.57
	44	Oranges	60	4.43	0.46	0.10	3.47	5.63

45	Pineapples	60	6.66	0.65	0.10	5.54	7.98
46	Sweet banana	60	3.35	0.28	0.08	2.71	3.91

Note: Authors' calculations, from Tanzania Bureau of Statistics (TBS) data.

Figure 1 and 2 show the results of CoNA under the higher productivity simulations. We see that price changes in Fruits and Vegetables have the greatest impact on CoNA in Ghana. For 10% price increase, the median CoNA increases by 4.8% from USD2.33 to USD2.44. A similar 10% decrease see the median CoNA drop by 5.0% from USD2.33 to USD2.21.

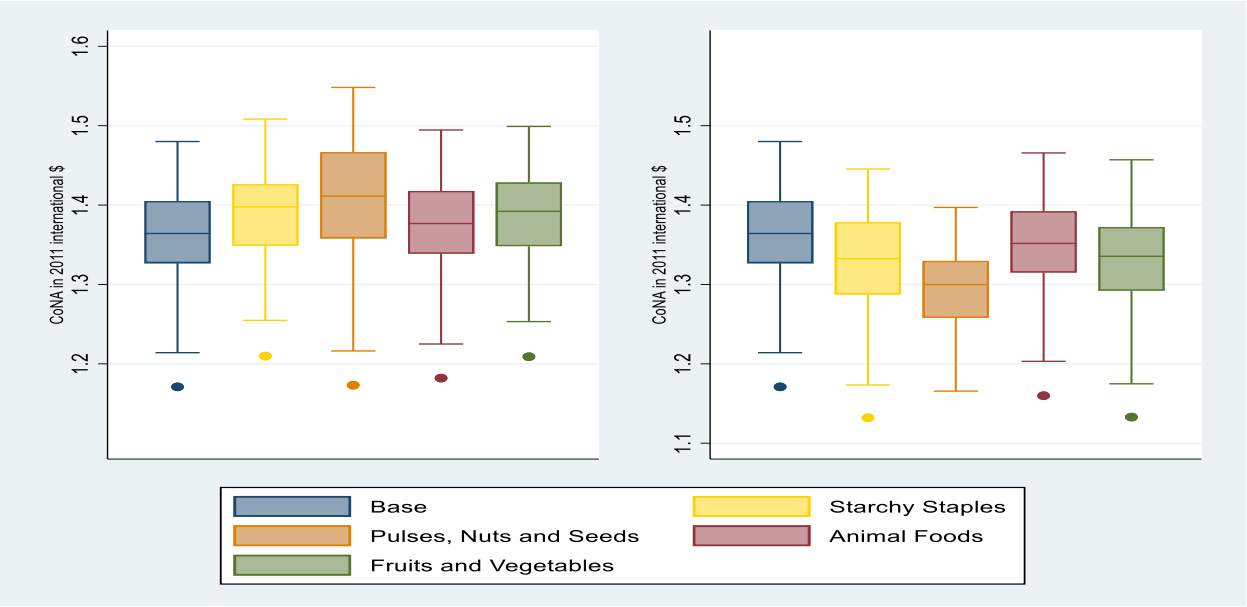
Figure 1. CoNA Indexes as Productivity Change in Ghana (Price +/- 10%)



Note: The middle line in the box shows the median value, and the upper and lower hinge of the box show 75th and 25th percentile of the distribution. The boundaries of the adjacent line show the upper and lower adjacent value. The points are the outliers of the distributions.

In Tanzania, price change in Pulses, Nuts and Seeds have the biggest influence on CoNA. For 10% price increase, the median CoNA increases by 3.4% from USD1.36 to USD1.41. Price change in Animal Foods have small impacts in both countries. For 10% price increase/decrease, CoNA may only shift by less than 1% (0.8% in Ghana and 0.9% in Tanzania).

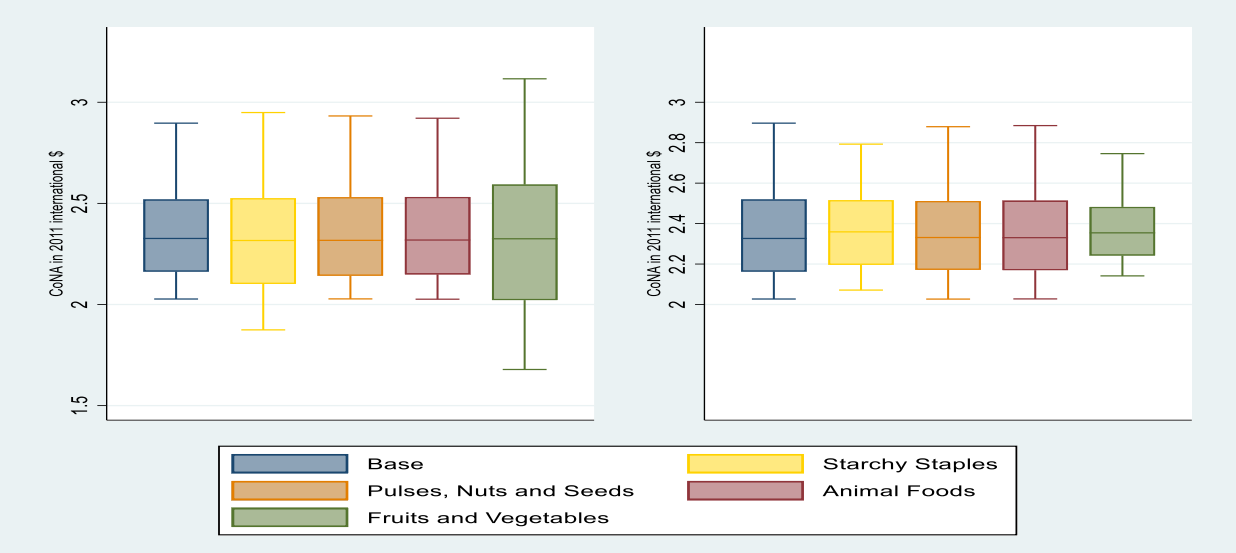
Figure 2. CoNA Indexes as Productivity Change in Tanzania (Price +/- 10%)



Note: The middle line in the box shows the median value, and the upper and lower hinge of the box show 75th and 25th percentile of the distribution. The boundaries of the adjacent line show the upper and lower adjacent value. The points are the outliers of the distributions.

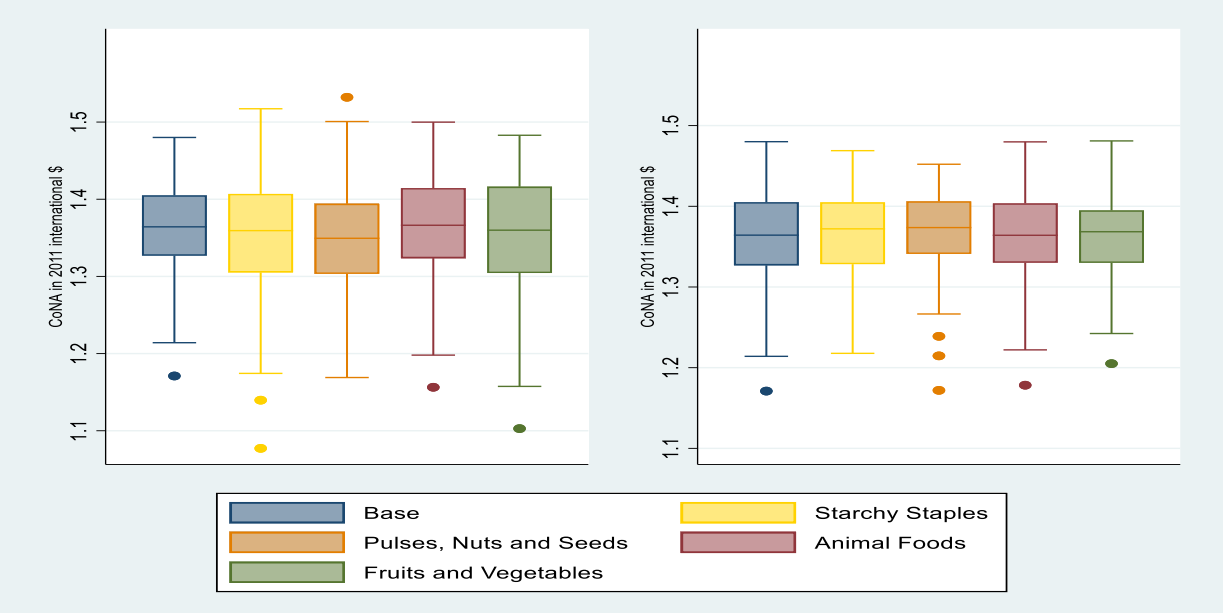
Figure 3 and 4 provides the results under the better markets where standard deviation of food prices in different categories is increased by 100% (doubled) or cut by 50% (halved). The results reveal that the food category of Fruits and Vegetables have much stronger impact on CoNA than all the others in both countries. We note the high PPP (USD) per kcal of fruits and vegetables in Ghana. If the standard deviation of all fruits and vegetables double, the standard deviation of CoNA would increase by 58% in Ghana and 30% in Tanzania. Similarly, a 50% cut in standard deviation of all fruits and vegetables would translate into a 30% reduction of the standard deviation of CoNA in Ghana, and a 12% reduction in Tanzania.

Figure 3. CoNA Indexes as Transportation/Storage Change in Ghana (SD ×/÷ 2)



Note: The middle line in the box shows the median value, and the upper and lower hinge of the box show 75th and 25th percentile of the distribution. The boundaries of the adjacent line show the upper and lower adjacent value. The points are the outliers of the distributions.

Figure 4. CoNA Indexes as Transportation/Storage Change in Tanzania (SD ×/÷ 2)



Note: The middle line in the box shows the median value, and the upper and lower hinge of the box show 75th and 25th percentile of the distribution. The boundaries of the adjacent line show the upper and lower adjacent value. The points are the outliers of the distributions.

In general, there are differences in the relative impact of the different food group prices on CoNA when prices change. Responses on impacts are lower in Tanzania than in Ghana, perhaps due to the more diversity in the food groups in Tanzania and relatively good domestic integration

of Tanzania (Breton, Portugal-Perez and Regolo, 2014) markets. CoNA responses to food price changes are all less than proportional (inelastic). It appears improvements in better market efficiency are more CoNA impacted than productivity increases, although both provides beneficial changes to CoNA.

6. Conclusions

This paper offers an analytical framework with which to measure the impacts of different kinds of systemic interventions on the overall cost of nutritious diets. Our approach is potentially applicable to many different kinds of interventions, from national policies targeting an entire sector to local programs for specific foods. In this framework paper, we consider only policies that are national in scope, dividing interventions into those that affect production levels and hence average prices, and those that affect transport or storage, better markets, and hence price differences over space and time. We also divide interventions by the type of food that is targeted, differentiating between starchy staples, leguminous grains, animal products or fruits and vegetables.

Our simulations suggest that for Ghana, the overall cost of nutritious diets is most sensitive to improvements in fruit and vegetable prices, whereas for Tanzania sensitivity is greatest for the level of leguminous grain prices as well as variation in fruit and vegetable prices. These simulations are based on least-cost diets designed to track the cost of essential nutrients for a healthy diet, without suggesting a diet plan, and are consistent with recommendations derived from other evidence. For example, Chagomoka *et al.*, (2015) suggest the importance of policy focus on vegetable production, particularly the dark-green leafy vegetables, in the provision of nutritious diets (consumption) in Ghana. In northern Ghana, they indicate that although green-leafy vegetables are grown and eaten at subsistence with more households in rural areas producing all the requirements of their vegetables compared to urban and peri-urban areas, rural areas had the lowest dietary diversity score with low consumption of the dark green vegetables. They suggest that the relatively higher dietary diversity score of urban households may be due to marketable surpluses of these vegetables at organized markets.

Results therefore point to opportunities for more investment targeting these specific objectives, but diet costs in both countries remain sensitive to the prices of starchy staples and animal

products. In our analytical framework, when an intervention successfully reduces the cost of one set of foods and associated nutrient needs, other nutrients become limiting factors and then different interventions are needed. This insight follows from our whole-of-diet approach, recognizing that meeting nutritional needs requires a balanced approach, targeting low and stable prices for all major food groups.

References:

Akhter, N. et al. (2018) Change in cost and affordability of a typical and nutritionally adequate diet among socio-economic groups in rural Nepal after the 2008 food price crisis., Food Security, 10(3), 615-629.

Allen, R. C. (2017) Absolute Poverty: When Necessity Displaces Desire, American Economic Review, 107(12), pp. 3690–3721.

Chagomoka, T. et al. (2015) Vegetable production, consumption and its contribution to diets along the urban – rural continuum in Northern Ghana., African Journal of Food, Agriculture, Nutrition and Development, 15(4), pp.10352-10367.

Chastre, C.; Duffield, A.; Kindness, H.; LeJeune, S.; Taylor, A. (2007) The Minimum Cost of a Healthy Diet. London: Save the Children UK. Available at: http://www.savethechildren.org.uk/resources/online-library/the-minimum-cost-of-a-healthy-diet.

Cofer, E. ; Grossman, E. ; Clark, F. (1962) Family food plans and food costs : for nutritionists and other leaders who develop or use food plans. Home Economics Research Report No. 20. U.S. Department of Agriculture, Agricultural Research Service, Consumer and Food Economics Research Division.

Deptford, A., Allieri, T., Childs, R., Damu, C., Ferguson, E., Hilton, J., Parham, P., Perry, A., Rees, A., Seddon, J. and Hall, A., 2017. Cost of the Diet: a method and software to calculate the lowest cost of meeting recommended intakes of energy and nutrients from local foods. BMC Nutrition, 3(1), p.26.

FAO (1996). Food security: concepts and measurement. Rome: FAO.

Fuglie, K. and Rada, N. (2013) Resources, Policies, and Agricultural Productivity in Sub-Saharan Africa, ERS Research Report 145. Washington, DC: USDA.

Gerdessen, J. C. and de Vries, J. H. M. (2015) Diet models with linear goal programming: impact of achievement functions, European Journal of Clinical Nutrition, 69(11), pp. 1272–1278.

Hirvonen, K., Y. Bai, D. Headey and W.A. Masters (2019). Affordability of healthy and sustainable diets: Global analysis of the EAT-Lancet reference diet relative to household income and the cost of nutrient adequacy. Lancet Global Health, forthcoming.

Mabe, F.N, Ehiakpor, D and Danso-Abbeam, G (2018). Assessment of Implementation of Planting for Food and Jobs (PFJ) Programme: Lessons and Way Forward. Feed the Future Ghana Agricultural Policy Support Project (APSP), USAID. Technical Paper, May.

Masters, W.A., Bai, Y., Herforth, A., Sarpong, D.B., Mishili, F., Kinabo, J. and Coates, J.C. (2018). Measuring the Affordability of Nutritious Diets in Africa: Price Indexes for Diet Diversity and the Cost of Nutrient Adequacy. American Journal of Agricultural Economics 100 (5), 1285–1301.

OBrien-Place, P. M. and Tomek, W. G. (1983) Inflation in Food Prices as Measured by Least-Cost Diets, American Journal of Agricultural Economics, 65(4), p. 781-784.

Omiat, G. and Shively, G. (2017) Charting the cost of nutritionally-adequate diets in Uganda, 2000-2011, African Journal of Food, Agriculture, Nutrition and Development, 17(1), pp. 11571–11591.

Optifood (2012) Optifood: An Approach to Improve Nutrition. ClinicalTrials.gov project NCT01646710. Available at: https://clinicaltrials.gov/ct2/show/NCT01646710

Parlesak, A., Tetens, I., Jensen, J.D., Smed, S., Blenkuš, M.G., Rayner, M., Darmon, N. and Robertson, A., 2016. Use of linear programming to develop cost-minimized nutritionally adequate health promoting food baskets. PLOS ONE, 11(10), p. e0163411.

Planting for Food and Jobs (PFJ) (2017). Ministry of Food and Agriculture, Republic of Ghana. Available at: http://mofa.gov.gh/site/wp-content/uploads/2018/03/PFJ%20document%20New%20New.pdf.

Regolo, J., Portugal-Perez, A. and Brenton, P. (2014) Food prices, road infrastructure, and market integration in Central and Eastern Africa. WPS7003. The World Bank, pp. 1–43.

Schneider, K. and Mary Kay Gugerty, P. (2011) Agricultural Productivity and Poverty Reduction: Linkages and Pathways, The Evans School Review, 1, pp. 56–74.

Stigler, G. J. (1945), The Cost of Subsistence, Journal of Farm Economics, 27(2), pp. 303-314.

The World Bank (2016), World Development Indicators. Washington, DC: The World Bank.

Vossenaar, M., Knight, F.A., Tumilowicz, A., Hotz, C., Chege, P. and Ferguson, E.L. (2017) Context-specific complementary feeding recommendations developed using Optifood could improve the diets of breast-fed infants and young children from diverse livelihood groups in northern Kenya, Public Health Nutrition, 20(6), pp. 971–983.

Appendix 1. Simulation Results of CoNA in Ghana (in 2011$)

Country/Case	Simulation Scenarios	Obs.	Mean	Std. Dev.	CV	Min	Max
Base	1. Base CoNA	60	2.39	0.27	0.11	2.03	2.90
Price + 10%	1. Starchy Staples	60	2.44	0.27	0.11	2.08	2.95
	2. Pulses, Nuts and Seeds	60	2.42	0.27	0.11	2.05	2.93
	3. Animal Foods	60	2.41	0.27	0.11	2.05	2.92
	4. Fruits and Vegetables	60	2.50	0.28	0.11	2.10	3.03
Price - 10%	1. Starchy Staples	60	2.33	0.25	0.11	1.97	2.82
	2. Pulses, Nuts and Seeds	60	2.37	0.26	0.11	2.00	2.87
	3. Animal Foods	60	2.37	0.26	0.11	2.01	2.87
	4. Fruits and Vegetables	60	2.27	0.24	0.11	1.94	2.73
Price SD ×2	1. Starchy Staples	60	2.36	0.31	0.13	1.87	2.95
	2. Pulses, Nuts and Seeds	60	2.39	0.28	0.12	2.03	2.93
	3. Animal Foods	60	2.39	0.28	0.12	2.03	2.92
	4. Fruits and Vegetables	60	2.37	0.42	0.18	1.68	3.12
Price SD ÷ 2	1. Starchy Staples	60	2.39	0.22	0.09	2.07	2.79
	2. Pulses, Nuts and Seeds	60	2.39	0.26	0.11	2.03	2.88
	3. Animal Foods	60	2.39	0.26	0.11	2.03	2.88
	4. Fruits and Vegetables	60	2.39	0.19	0.08	2.14	2.75

Appendix 2. Simulation Results of CoNA in Tanzania (in 2011$)

Country/Case	Simulation Scenarios	Obs.	Mean	Std. Dev.	CV	Min	Max
Base	1. Base CoNA	60	1.36	0.06	0.05	1.17	1.48
Price + 10%	1. Starchy Staples	60	1.39	0.06	0.04	1.21	1.51
	2. Pulses, Nuts and Seeds	60	1.40	0.08	0.06	1.17	1.55
	3. Animal Foods	60	1.38	0.06	0.05	1.18	1.49
	4. Fruits and Vegetables	60	1.39	0.06	0.04	1.21	1.50
Price - 10%	1. Starchy Staples	60	1.33	0.07	0.05	1.13	1.45
	2. Pulses, Nuts and Seeds	60	1.29	0.05	0.04	1.17	1.40
	3. Animal Foods	60	1.35	0.06	0.05	1.16	1.47
	4. Fruits and Vegetables	60	1.33	0.07	0.05	1.13	1.46
Price SD ×2	1. Starchy Staples	60	1.35	0.09	0.07	1.08	1.52
	2. Pulses, Nuts and Seeds	60	1.35	0.07	0.06	1.17	1.53
	3. Animal Foods	60	1.36	0.07	0.05	1.16	1.50
	4. Fruits and Vegetables	60	1.35	0.08	0.06	1.10	1.48
Price SD ÷ 2	1. Starchy Staples	60	1.37	0.05	0.04	1.22	1.47
	2. Pulses, Nuts and Seeds	60	1.37	0.06	0.04	1.17	1.45
	3. Animal Foods	60	1.36	0.06	0.04	1.18	1.48
	4. Fruits and Vegetables	60	1.36	0.05	0.04	1.21	1.48