Charting the cost of nutritionally-adequate diets in Uganda, 2000-2011

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ABSTRACT. Malnutrition rates have been on the decline in Uganda over the past two decades but remain above targets set as part of the Millennium Development Goal (MDG). Challenges to achieving nutritional improvements result, in part, from high staple foods prices, which raise the cost of the food basket and increase the risk of food and nutrition insecurity, especially for poor households who are net buyers of staple foods. In this paper we measure the cost of a nutritionally-adequate diet in Uganda across locations and over time. We use a linear programming model and observed prices to compute the lowest-cost diet in five markets, subject to a range of nutrient-specific constraints. We compare this cost to the Ugandan poverty line over the same period. We show that the real cost of obtaining a nutritionally-adequate diet grew at a rate of 3 to 9 percent per year over the period 2000 to 2011. Diet costs have exceeded the poverty line for most years since 2000, with the gap widening in the period 2007-2008. Our results highlight the importance of food prices to overall nutrition, and document spatial heterogeneity in diet costs in Uganda. Findings underscore the importance of developing and supporting interventions that raise the purchasing power of the poor and increase nutrition education and outreach aimed at cost-effectively achieving dietary diversity.

Key words: food prices, malnutrition, markets, Uganda

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1. Introduction

This paper asks whether high food prices pose a threat to healthy diets in Uganda. The answer, not surprisingly, is yes. Nearly two-thirds of Ugandan households are net buyers of staples (Benson et al., 2008), a pattern that underscores the potential importance of food prices as a driver of food insecurity. Although child malnutrition rates in Uganda have been on the decline over the past two decades, during 2007-2008 the country experienced sharp increases in the prices of key staple foods. When food prices increase, households often turn to cheaper and/or inferior sources of calories and nutrients, affecting not only overall food consumption but also diet quality and diversity, with potentially serious consequences for the nutrition and health of pregnant women, infants and young children (World Bank and International Monetary Fund, 2012). High food prices in Uganda have been widely perceived as undermining food security and slowing progress toward achieving the Millennium Development Goal (MDG) of halving rates of underweight in children under age five by 2015.

Below, we measure the cost of a nutritionally adequate diet in Uganda, asking how changes in domestic food prices have affected the cost of purchasing a diet that meets recommended minimum dietary requirements. Using monthly market price data for ten major food items in five key regions of the country we calculate the historical cost of obtaining a nutritionally adequate staple food diet. We solve our least-cost diet models at monthly time steps to obtain a price-sensitive "optimal" food basket that satisfies a set of 14 nutrient requirements as well as food size portion and food habit (palatability) constraints. We find that, even allowing for the adjustment of the food basket to changes in food prices, the real cost of a nutritionally-adequate diet grew at a rate of 3-9 percent over the period 2000 to 2011. Results that account for the typical food habits of Ugandan households show that food costs have been above the poverty line for most years since 2000, with the gap widening sharply in the period 2007-2008.

2. Approach

We use Linear Programming (LP) to solve the least-cost diet problem. LP has been used in many settings to find nutritionally-adequate least-cost diets. Stigler (1945) was the first to formally outline the least-cost diet problem, and Dantzig (1963) was the first to obtain an exact solution to Stigler's problem. Smith (1959), building on Stigler's work, incorporated palatability constraints to account for tastes and habits. Foytik (1981) developed an LP model that included palatability constraints, so as to ensure the inclusion of a wide range of foods in the optimal basket. Some of the palatability constraints Foytik used specified exact amounts of foods while other constraints represented food groups with minimum or maximum limits for particular items. O'Brien-Place and Tomek (1983) used an LP model with palatability constraints, some of which were incorporated as combinations of several foods, with upper and lower limits derived from food consumption patterns observed in household consumption surveys.

More recently, Darmon and Drewnowski (2015) reviewed a wide range of studies to examine whether nutrient-rich foods and higher-quality diets cost more in different societies. They also used a national database of commonly consumed foods in France to model dietary choices as a way of determining whether food prices pose a barrier to adopting healthy diets. Okubo et al. (2015) used an LP model to generate nutritionally-optimal Japanese food intake patterns that meet recommended Dietary Reference Intakes (DRIs). Bechman et al. (2015), for Mali, and Ryan et al. (2014), for Ethiopia, both used LP methods to develop ready-to-use therapeutic food (RUTF) formulations. And Darmon et al. (2006) used LP to identify nutritionally-adequate diets based on food recommendations for French women from different income groups living with different food budgets.

2.1 Least-cost diet Problem

Our model to find the lowest-cost diet is an LP that minimizes food costs subject to nutrient and portion constraints. The model can be expressed as:

$$\text{Minimize } C = \sum p_j \times f_j \tag{1}$$

subject to:

$$\sum a_{ij} \times f_j \geq R_i \tag{2}$$

$$f_j \leq M_j \times \sum f_j \tag{3}$$

$$f_j \geq 0, p_j \geq 0, a_{ij} \geq 0 \text{ for } (i = 1,2, \dots, m) \text{ and } (j = 1,2, \dots, n) \tag{4}$$

where

C is the total daily cost of the diet;

p_j is the price for a 100 gram portion of jth food item;

f_j is the optimal amount of the jth food item to be consumed;

R_i is the nutritional requirement for the ith nutrient;

a_{ij} is the nutritional composition unit obtained from the jth food item for the ith nutrient;

M_j is the maximum portion size for the jth food.

All nutrients are measured as Recommended Dietary Allowances (RDAs), essential for adequate nutrition. RDAs and maximum portion sizes are measured per 100 grams of the jth food item and come from estimates for Uganda provided by Hotz et al. (2012).

2.2 Data

Equation (1) represents the food costs that are to be minimized. Our food price data are retail prices obtained from two sources, FoodNet and FIT-Uganda.[1] FoodNet retail price data cover 28 commodities and were collected from 4 markets in Kampala, and 19 district markets in Uganda, They cover the period September 1999 to July 2008. FIT-Uganda retail price data cover 40 commodities and 22 district markets over the period July 2008 to December 2011. Prices used to compute the minimum cost of a diet are reported in Ugandan shillings per kilogram. To compare food costs over time, we have deflated prices using the monthly consumer price index (CPI). The food prices used in the analysis were converted to prices per 100 gram portions p_j, so as to maintain consistency with the unit of nutrient composition for a given food item.

Equation (2) represents the minimum nutrient intake levels, i.e. the RDA constraints. The R_j values used in our analysis are listed in Table 1. The entries in Table 1 correspond to a representative Ugandan man and woman aged 19-50. For example, from Table 1 the recommended calorie intake is 2,990 calories per day for a man aged 19-50, and 2,301 for a woman aged 19-50 years. The source of these RDAs is the United

[1] FoodNet was started in 1999 by the Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA) and implemented by the International Institute of Tropical Agriculture (IITA). FIT-Uganda, was started by infotrade in 2008 in partnership with the Danish International Development Assistance's Agricultural Sector Programme Support (ASPS-DANIDA).

States Department of Agriculture (USDA), which regularly revises (every five years) and publishes Dietary Reference Intakes (DRI) recommend by the Food and Nutrition board. The nutrient constraints used in the analysis are the 14 nutritional requirements shown in Table 1.

The nutrition composition data a_{ij} for staple foods used in our analysis are listed in Table 3. The nutrient food composition data were obtained from a Food Composition Table (FCT) developed by HarvestPlus for Central and Eastern Uganda (Hotz et al., 2012). All FCT data used in the analysis are expressed in units per 100 grams of food. The selected staple food commodities listed in Table 3 are the main staple foods consumed by most households in Uganda (Chauvin, Mulangu and Porto, 2012; Haggblade and Dewina, 2010; USAID and COMPETE, 2010). The main staple foods include: *matooke* (plantain), cassava, maize, millet, rice, beans and groundnuts. These foods are those for which prices data are available. The list excludes for foods for which no price information was available. These include vegetables, meats and fish, milk, eggs, beverages, sugars, salt and spices, and fats and oils.

Equation (3) represents the maximum food size portion or food habit (palatability) of staple food used in our analysis. The maximum ingredient portion size M_j, used in home prepared recipes are obtained from the HarvestPlus Food Composition Table (FCT) (Hotz et al., 2012). These food size portion constraints are imposed to ensure that the least-cost diet obtained is within the range of estimated food size portions used in home prepared recipes for composite dishes of food consumed in Uganda. The maximum food size portion in home prepared recipes (in weight) are shown in Table 4. These range from 8 percent (for millet flour) to 75 percent (for *matooke*).

The least-cost LP problem was solved separately for a representative man and woman for each month in the 12-year period January 2000 to December 2011. Each trajectory of was generated using 144 solutions to the LP problem, using prices observed in five districts in representative regions of the country (Kampala, Lira, Iganga, Masaka, and Mbarara – see Table 5). We solved two versions of the model: one with minimum RDAs (the *basic diet*), and one incorporating both the minimum RDAs and maximum portion size constraints (a *constrained diet*). In general, the constrained diet produces more realistic solutions for the least-cost diet because the food size portion constraints more accurately represent the food habits of Ugandan households.[2]

The main limitation in obtaining a least-cost diet using our LP approach is the number of food items from which we are able to construct the least-cost basket. For example, staples such as sweet potatoes, Irish potatoes and sorghum are important in some regions of Uganda but cannot be included in the analysis because of incomplete or unavailable price data. Including these food staples would likely result in lower cost diets than those obtained here. It is also possible that including vegetables, especially those that are common in home recipes and provide a rich source of nutrients, could lead to lower cost diets, but prices for vegetables, especially leafy vegetables also are not available. In addition, it is important to underscore that our analysis focuses on an average adult man and woman. While the nutritional needs of these representative individuals are indicative, results from this analysis could be extended to examine the nutritional needs of a typical household, or those of at-risk individuals, such as children or pregnant women. Overcoming these limitations will require more data. An additional extension to this analysis would be to expand the set of constraints used in the model to focus not only on RDAs, but also on observed food habits based on consumption patterns obtained from household consumption and expenditure surveys.

3. Results

The costs over time of the least-cost diets for the period January 2000 to December 2011 are presented in figures 1-4. Figures 1 and 2 track the least-cost basic diet for the representative adult man and woman. Figures 3 and 4 track the cost of the constrained diet. The figures show that the real cost of all nutritionally-adequate diets has been trending upwards over the past 12 years.

The annual growth rates for these optimal diets are presented in Table 8. The annual growth rate in the cost of a nutritionally adequate diet ranges from 3.6 to 6.3 percent per year for the basic diet, and 3.0 to 9.2 percent per year for the constrained diet. Mbarara district experienced the fastest growth in diet cost and Masaka

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[2] Feasible solutions could not be obtained for diets incorporating both minimum RDAs and maximum tolerable daily limits. In other words, we were unable to find a set of staple foods at any cost that could simultaneously satisfy the minimum and maximum nutrient levels.

experienced the slowest growth in cost. The results in Table 6 show that, based on results from the constrained diet, the annual increase in diet cost for Masaka district was 3.1 percent (for a woman) and 3.0 percent (for a man). In Mbarara district, the annual increases were 9.2 percent (for a woman) and 8.9 percent (for a man).

As a frame of reference, figures 1-4 include a basic poverty line, computed using the World Bank's global poverty standard of $1.25 a day and converted to local currency units (LCU) using a purchasing power parity (PPP) exchange rate. The cost of the basic diet was very near and roughly followed the poverty line for most years and most locations over the period 2000 to 2011 (see figures 1 and 2). The gap between the poverty line and the diet cost widened between 2007 and 2011, which coincides with the period in which Uganda experienced a sharp rise in the price of most staple foods. When we compare the poverty line to the cost of the constrained diet we see that food costs were above the poverty line for most years and in most locations (see figures 3 and 4). The difference in the trends between the basic and constrained diets shows the impact of accounting for the food habits of households, as well as upper limits on consumption of particular food items. The costs of the basic diet and the constrained diet are compared in Figure 5 for a representative woman in Kampala. When we compare food costs from the basic and constrained diets for the period between 2007 and 2011 we see that, for the basic diet, food costs are above the poverty line for the period 2007-2008, but below the poverty line for the period 2009-2011. For the constrained diet the cost of the optimal basket is well above the poverty line in most years and in most locations. This suggests that the rise in staple food prices in 2007-2008 raised food costs for many poor households that consume a diet that relies heavily on staple foods.

To provide a snapshot of the "typical" optimal baskets selected by the model, Table 5 presents the average diet composition. For the basic diet, the four main food staples that constitute the least-cost diet are fresh cassava, cassava flour, beans, and groundnuts. For the constrained diet, the basket includes five main food staples: fresh cassava, cassava flour, *matooke*, beans, and groundnuts. Fresh cassava, cassava flour and *matooke* are main sources of carbohydrates in the staple food diet while beans and groundnuts are main sources of protein. The basic diet for a woman aged 19-50 years in Kampala consists, on average, of 183.2 kilograms of fresh cassava per year, 12.2 kilograms of cassava flour, 294.7 kilograms of beans, and 30.4 kilograms of groundnuts.

A closer look at this diet reveals that the protein sources – beans and groundnuts – account for more than half (62.5 percent) of the diet, which is unreasonably high compared with a safe level of protein consumption (WHO, FAO and UNU Expert Consultation, 2007).

A more reasonable diet accounts for individual preferences and palatability, based on RDAs and food size portions in home recipes. In this constrained diet, protein sources account for 18 to 26 percent of the diet (by weight). For example, a typical annual diet for a woman aged 19-50 years in Kampala consists of 429.1 kilograms of fresh cassava, 154.2 kilograms of cassava flour, 212.1 kilograms of *matooke*, 202.3 kilograms of beans, and 30.5 kilograms of groundnuts per year. In this diet, protein sources account for about 23 percent of the staple diet (see Table 7). Including the food size portion or palatability constraints provides a more realistic solution than using the RDAs alone.

4. Conclusions and policy implications

The cost of a nutritionally-adequate diet in Uganda grew over the period 2000 to 2011. The cost of the basic least-cost diet has grown at a rate of 3.6 to 6.3 percent per year. When we account for food habits using food size portions from home prepared recipes, we show that food costs have grown at a rate of about 3.0 to 9.2 percent per year. Although our models capture only the costs of staple foods, results suggest that food costs have been increasing for many poor households in Uganda, especially those that rely on food purchases. Moreover, when we consider computed food costs using Ugandan food habits, which provides a fairly realistic food basket, we find that food costs have been above the poverty line for most years with the gap widening in the period 2007-2008, when staple food prices increased sharply in Uganda.

Although the results of this analysis do not directly inform efforts to improve nutrition education and outreach, it is nevertheless clear that finding ways to help households make wise food choices and develop good food habits will improve the cost-efficiency of food purchase decisions. When it is relatively costly to meet nutritional needs, as our analysis suggests it has been in Uganda, and where households face challenges to affordability, getting the greatest nutrition benefit from food expenditures is important. Our results therefore support the idea that nutrition policies should aim to support healthy food choices in Uganda. In developing nutrition policies the focus should be on nutrition interventions such as household nutrition education and outreach programs, and the development and dissemination of national nutrition or dietary guidelines. This will be especially important when households are faced with high market prices, and must make decisions about which staples to substitute while conforming to food habits. However, nutrition education alone will not be enough to ensure access to nutritionally-adequate diets. Outreach must be combined with policies that aim to raise incomes, improve food security, and lower food costs. Strategies to accomplish these goals include stimulating staple food supply response, improving staple food storage and access to market information systems, and investments in basic market and transport infrastructure, which will help to moderate food price increases and price volatility.

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Table 1. Nutritional requirements for representative adult man and woman

			Recommended intake per day		Tolerable intake per day	
		Units	Male	Female	Male	Female
1	Energy	Kilo calories	2990	2301		
2	Protein	Grams	56	44		
3	Fat	Grams	66	51		
4	Carbohydrate	Grams	336	259		
5	Calcium	Milligrams	1000	1000	2500	2500
6	Iron	Milligrams	8	18	45	45
7	Zinc	Milligrams	11	8	40	40
8	Vitamin C	Milligrams	90	75	2000	2000
9	Thiamin	Milligrams	1.2	1.1		
10	Riboflavin	Milligrams	1.3	1.1		
11	Niacin	Milligrams	16	14	35	35
12	Vitamin B6	Milligrams	1.3	1.3	100	100
13	Folate	Micrograms	400	400	1000	1000
14	Vitamin A	Micrograms	900	700	3000	3000

Source: USDA, National Agricultural Library, Food and Nutrition Information Center. Interactive DRI for Healthcare Professionals.
http://fnic.nal.usda.gov/fnic/interactiveDRI/dri_results.php

Table 2. Anthropometric information for consumers in model

	Male	Female
Height (cm)	173.7	158.8
Weight (kgs)	60.2	56.5
Age (year)	25	25

Source: Garenne (2011)

Table 3. Nutrient food composition data of staple foods

Nutrients (per 100 gm)	Unit	Staple Foods: Maize flour	Millet flour	Rice	Cassava fresh	Cassava flour	*Matooke* (plantain)	Beans	Groundnut
Energy	Kilocalories	369	374	360	160	314	122	347	567
Protein	Grams	7.3	10.9	6.6	1.4	2.6	1.3	21.4	25.8
Fat	Grams	1.8	4.2	0.6	0.3	0.7	0.4	1.2	49.2
Carbohydrate	Grams	79.2	72.1	79.3	38.1	76.6	31.9	62.6	16.1
Calcium	Milligrams	3.0	8.0	9.0	16.0	31.0	3.0	113.0	92.0
Iron	Milligrams	1.1	3.0	0.8	0.3	1.9	0.6	5.1	4.6
Zinc	Milligrams	0.7	1.7	1.2	0.3	0.7	0.1	2.3	3.3
Vitamin C	Milligrams	0.0	0.0	0.0	20.6	72.0	18.4	6.3	0.0
Thiamin	Milligrams	0.140	0.416	0.070	0.087	0.310	0.052	0.713	0.640
Riboflavin	Milligrams	0.050	0.287	0.048	0.048	0.050	0.054	0.212	0.135
Niacin	Milligrams	1.000	4.668	1.600	0.854	1.400	0.686	1.174	12.066
Vitamin B6	Milligrams	0.198	0.380	0.145	0.088	0.700	0.299	0.474	0.348
Folate	Micrograms	30	84	9	27	36	22	525	240
Vitamin A	Micrograms	0	0	0	1	7	56	0	0

Source: Hotz et al. (2012)

Table 4. Maximum portion sizes, proportion of total grams

Commodity	Maximum portion size (% of total weight)
Carbohydrates	
Maize flour	0.35
Millet flour	0.08
Rice	0.35
Cassava fresh	0.70
Cassava flour	0.35
Matooke (plantain)	0.75
Protein	
Beans	0.25
Groundnut	0.25

Source: Hotz et al. (2012)

Table 5. District/market and location

District/market	Location
Kampala	Central - central market
Lira	North
Iganga	East
Masaka	Central
Mbarara	Southwest

Source: District Map of Uganda

Table 6. Annual cost growth rates of least-cost diet for five districts, 2000-2011

	Districts/markets				
Diet	Kampala	Lira	Iganga	Masaka	Mbarara
Basic (RDAs only)					
Man	5.92	4.17	4.51	3.61	6.13
Woman	6.06	4.33	4.71	3.84	6.25
Constrained (RDAs and palatability)					
Man	6.49	6.77	4.70	2.99	8.91
Woman	6.63	7.04	4.86	3.09	9.17

Source: Authors calculations

Note: Annual growth rates in diet costs are estimated using the regression $\ln Cost_t = \alpha + \beta t$, where t is year.

Table 7: Average amount of staple food in least-cost diet, 2000-2011

	Kampala		Lira		Iganga		Masaka		Mbarara	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Basic										
Cassava fresh	207.5	183.2	268.0	246.7	120.4	33.8	1156.6	1178.4	323.2	304.5
Cassava flour	20.8	12.2	31.4	23.2	112.9	106.2	42.9	35.1	20.8	12.2
Matooke							80.2	47.0		
Beans	283.0	294.7	281.0	293.5	270.0	277.0	283.4	294.9	280.8	293.4
Groundnuts	41.7	30.4	41.3	30.0	66.8	58.9	41.5	30.2	41.4	30.1
Constrained										
Maize flour			293.2	300.8						
Millet flour			60.5	62.0						
Cassava fresh	413.5	429.1	510.1	525.3	318.3	331.5	407.6	421.5	500.0	515.2
Cassava flour	144.9	154.2	90.2	100.3	197.3	204.9	159.5	168.7	106.9	116.3
Matooke	195.4	212.1	98.9	114.8	212.7	231.6	262.1	282.7	56.2	70.1
Beans	197.5	202.3	202.1	207.3	185.4	189.3	209.5	215.0	200.0	205.2
Groundnuts	41.7	30.5	44.5	33.8	61.8	52.7	44.7	33.8	48.8	38.5

Source: Authors calculations

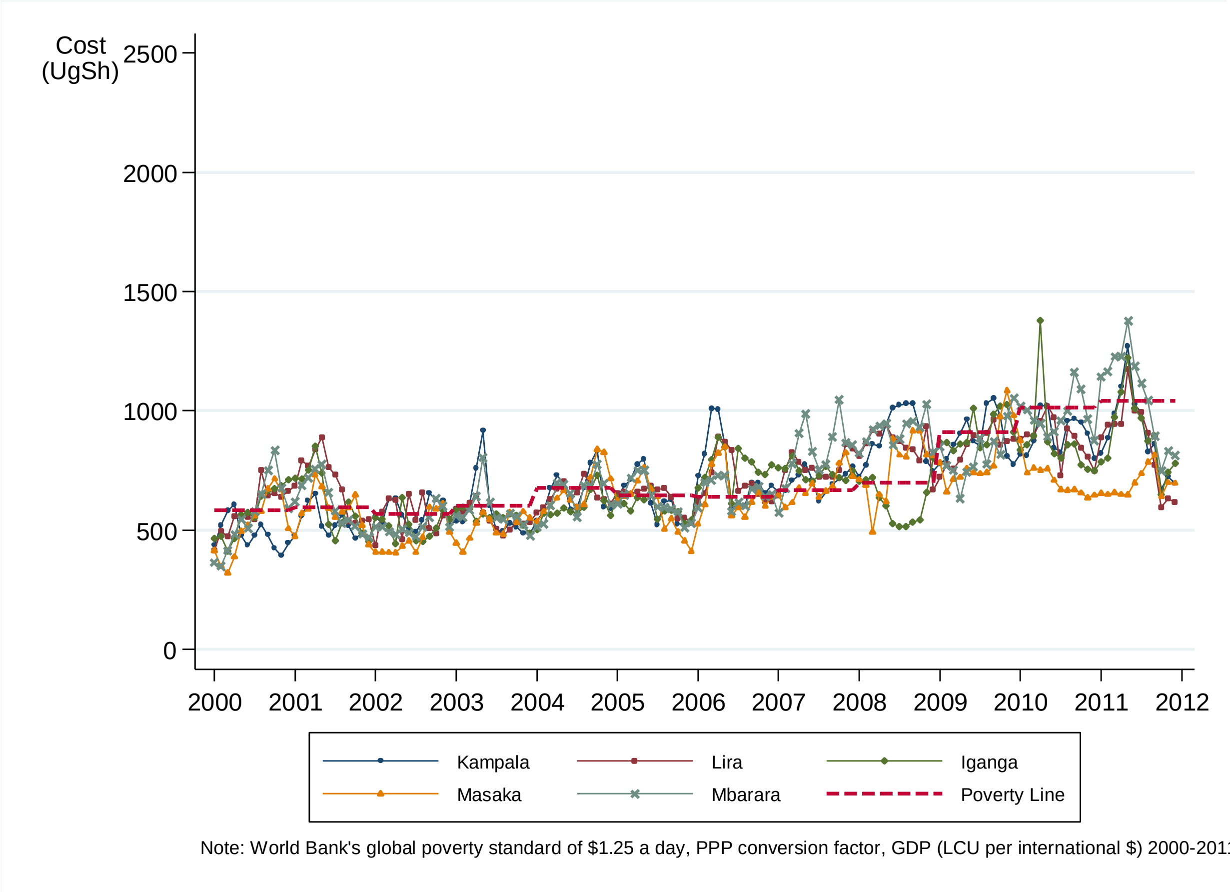

Figure 1: Cost of a nutritionally-adequate diet for an adult woman in Uganda, 2000-2011 (basic diet)

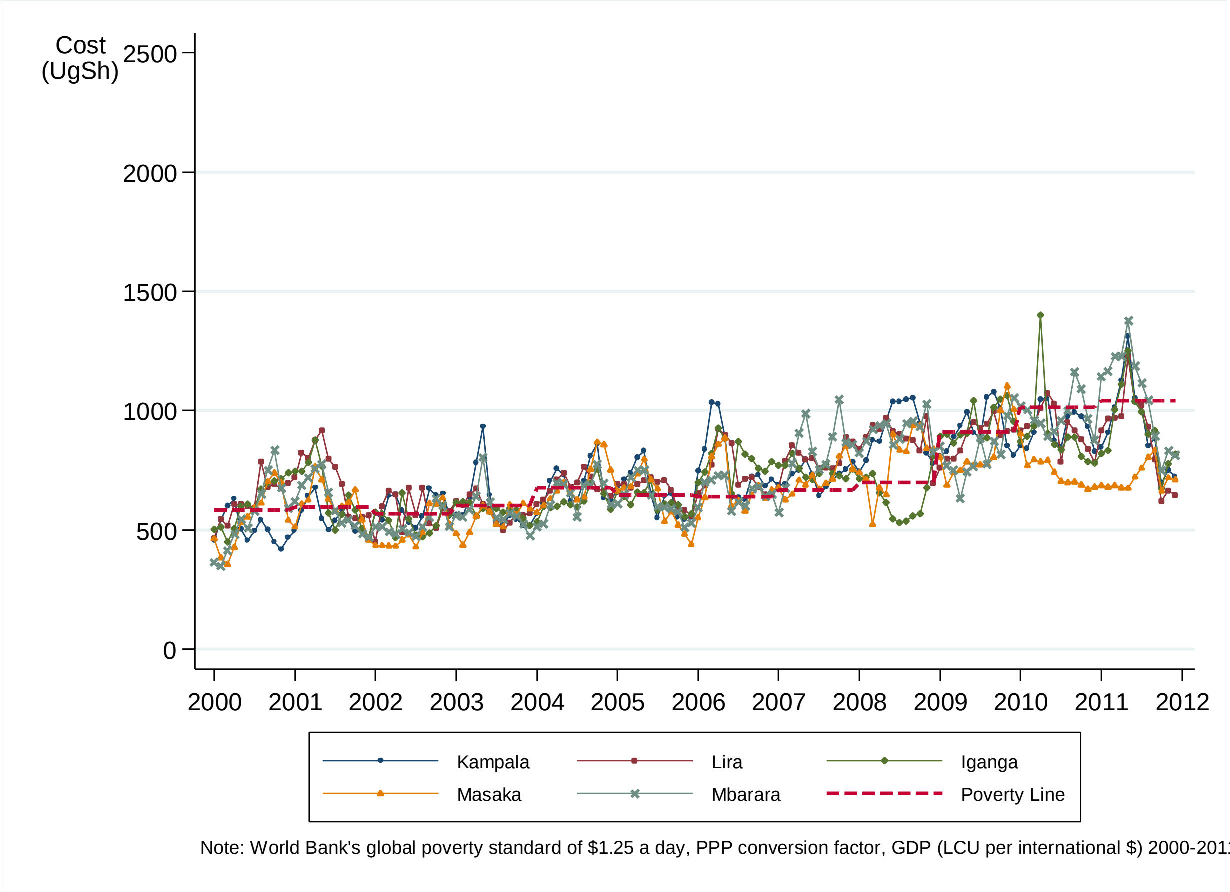

Figure 2: Cost of a nutritionally-adequate diet for an adult man in Uganda, 2000-2011 (basic diet)

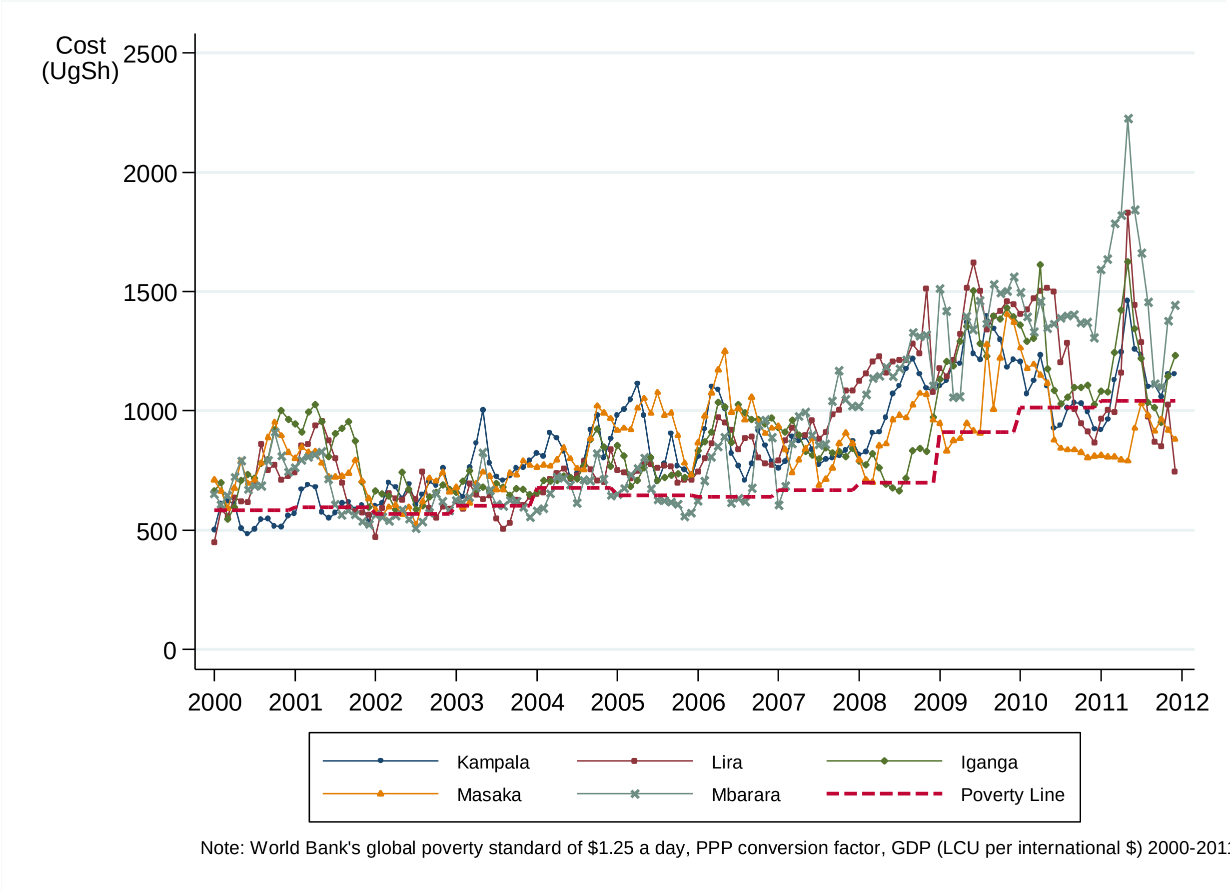

Figure 3: Cost of a nutritionally-adequate diet for an adult woman in Uganda, 2000-2011 (constrained diet)

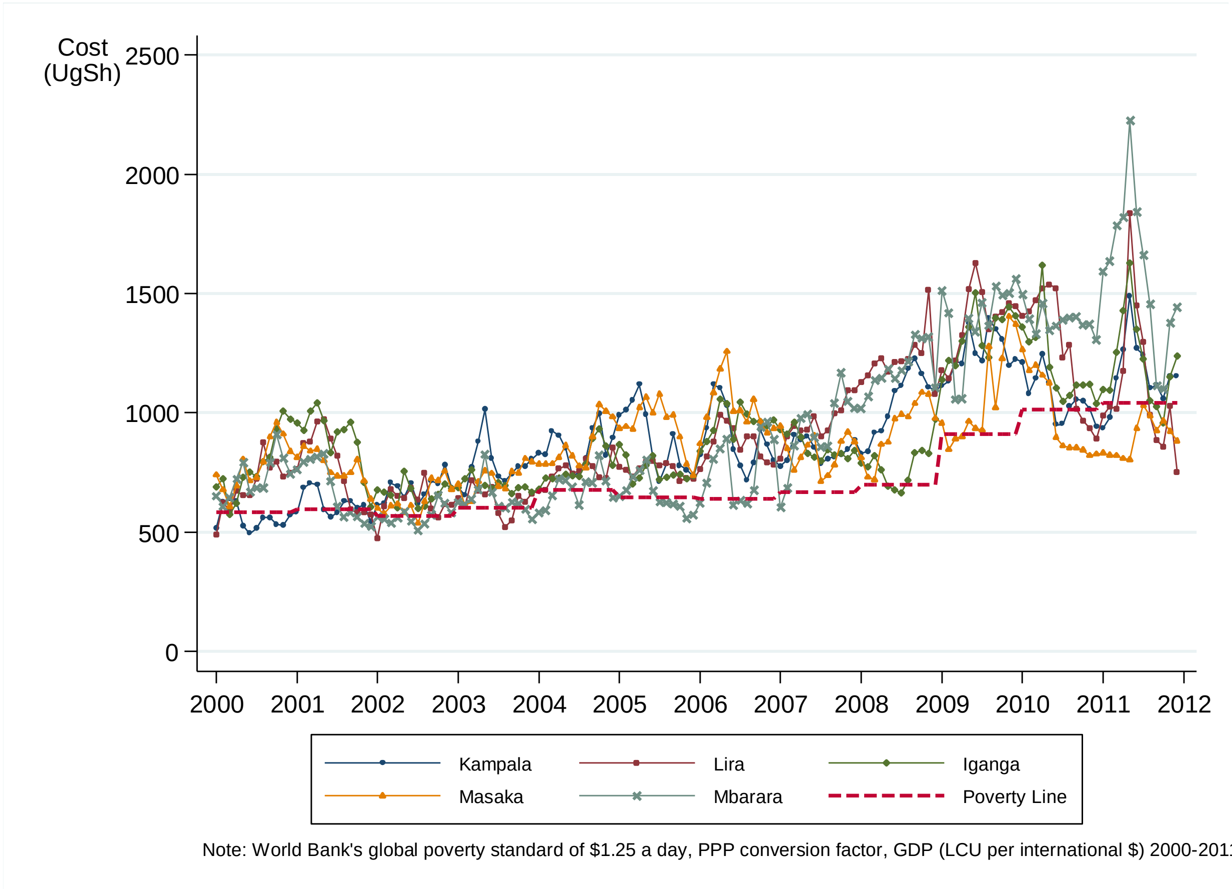

Figure 4: Cost of a nutritionally-adequate diet for an adult man in Uganda, 2000-2011 (constrained diet)

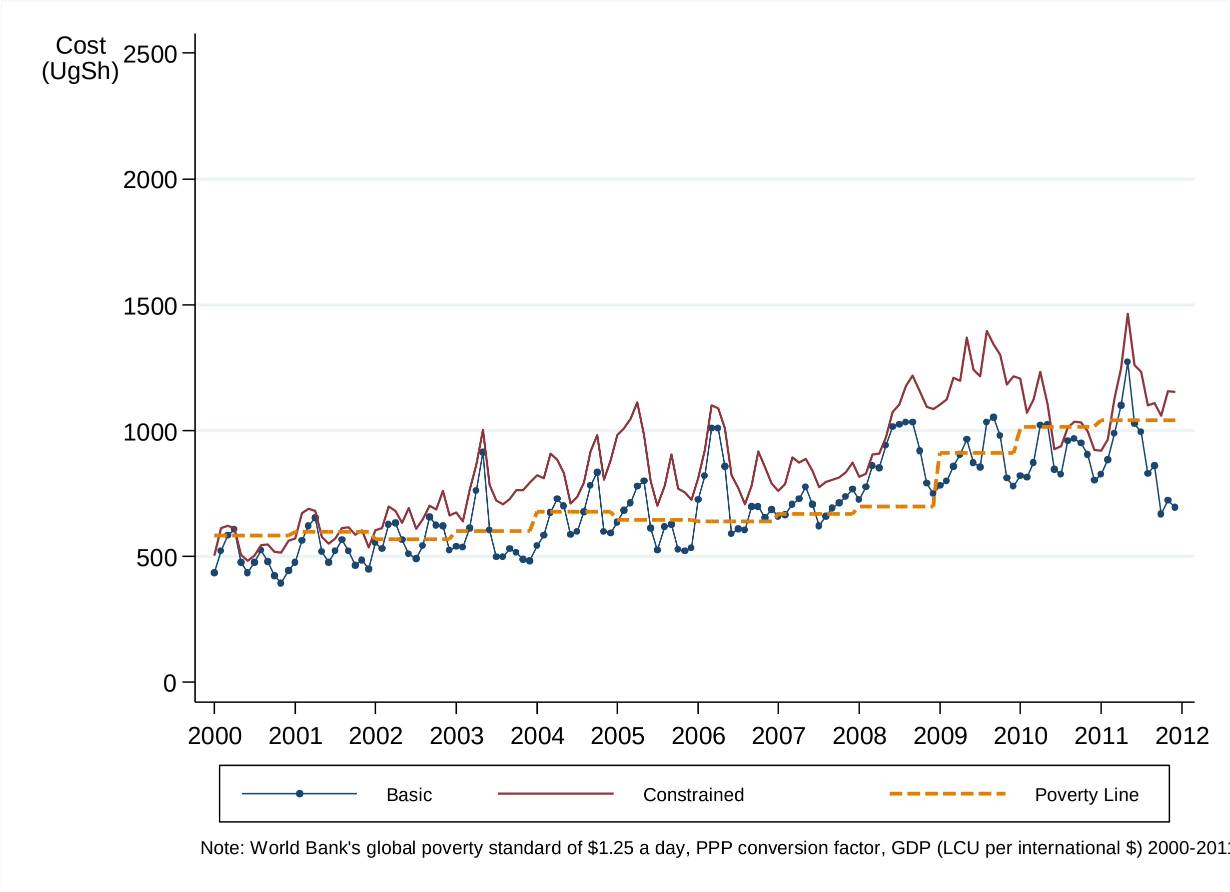

Figure 5: Cost comparison of basic and constrained diets for an adult woman in Uganda, 2000-2011 (Kampala market)