Do remote rural people pay higher prices for more nutritious foods? Evidence from 130,975 price observations at rural markets in Malawi, 2007-2017

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Abstract

This study tests for systematic differences in relative costs between boma versus remote rural markets and provides a novel test of price differences over the entire mix of foods needed for nutrient adequacy, relative to the cost of caloric adequacy, from the least-cost foods available in each month at each market in Malawi. We use prices for 55 food items, collected over 129 months from 2007-2017 in 29 locations. Contrary to our own expectations, we find that the costs of nutritious diets and daily energy from starchy staples are lower in more remote rural markets, due to lower prices in several food categories such as dried chambo and utaka, beef, powdered milk, and chicken eggs. Only fresh chambo is more expensive in more rural remote markets. The difference in overall diet cost is about 8%, at 1.48 vs. 1.61 USD/day in 2011 US$ PPP terms ($p<0.001$) for nutritious diets and about 26%, at 0.75 vs. 1.01 USD/day in 2011 US$ PPP terms ($p<0.001$) for daily energy from starchy staples. This finding provides suggestive evidence that poorer diet quality in more remote rural areas, if any, would be due to lower incomes and purchasing power rather than higher relative prices as had been hypothesized for this study, although more remote rural markets may be characterized by greater seasonality and other kinds of variation than boma market locations.

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1. Motivation

Retail prices for nutrient-rich foods such as milk, eggs, fruits and vegetables could play an important role in food selection and therefore diet quality. The costs of nutrient-dense foods are higher than the costs of energy-dense foods composed of refined grain, added sugars, and fats (Drewnowski *et al.,* 2004; Maillot *et al*., 2010; Rao *et al*., 2013; Global Panel on Agriculture and Food Systems for Nutrition, 2016; Dizon and Herforth, 2018). As a result, low-income consumers are more likely to choose diets with fewer micronutrients needed for long-term health because they provide dietary energy at the lowest possible costs (Darmon *et al*., 2002; Darmon *et al*., 2004; Darmon and Drewnowski, 2015; Green *et al.,* 2013; Miller *et al*., 2016). However, poor quality diets are associated with more unfavorable health outcomes such as obesity, hypertension, diabetes, heart disease, stroke and cancer (James *et al.,* 1997; Rao *et al*., 2013; Darmon and Drewnowski, 2015). Conversely, food choices are also influenced by many other factors such as tastes and habits, time constraints, nutrition knowledge and beliefs, and food availability (Smith, 1959; Allen, 2017; Mulik and Haynes-Maslow, 2017; Dizon and Herforth, 2018).

Linear optimization approach has been widely used to estimate the cost of the least diet required to meet a set of micronutrients needed for long-term health using food prices (Stigler, 1945; Smith, 1959; O'Brien-Place and Tomek, 1983; Chastre et al., 2007; Håkansson, 2015; Allen, 2017). There is a small but growing literature that has extended this previous work to estimate the cost of nutritious diets among food groups using food price data collected by either National Statistical Bureaus for computation of Consumer Price Indexes (CPIs) to monitor inflation or Ministry of Agriculture for agricultural market information system (AMIS) (see, for example, Masters *et al.*, 2018; Bai *et al*., 2018; Dizon and Herforth, 2018). This is driven by the fact that CPI measures the cost of living using weights derived from observed expenditure shares, without data on the health consequences associated with each type of food item consumed (International Labour Organization *et al.,* 2004). Hence, expenditures in the CPI are a poor indicator for the cost of nutritious diets. According to Dizon and Herforth (2018), estimation of the cost of nutritious diets through the food group approach involves classifying the CPI food items into various food groups that account for nutrition. The general findings from these studies are that the nutrient-dense foods are less affordable than energy-dense foods and their costs vary across seasons, place and time.

Beyond these contributions, this study makes two additional contributions to the existing literature. First, this is the only study to date that describes how retail prices for different kinds of food are collected, and

how prices differ by type of retail outlet in a low-income country with rapidly changing food system. To determine how relative food prices vary across different retail environments, we test for systematic differences in relative costs between boma 'rural town' versus more remote rural markets in Malawi. Second, this study provides a novel test of price differences over the entire mix of foods needed for nutrient adequacy, relative to the cost of subsistence from its cheapest source, comparing boma versus more remote rural markets. We define 'more remote' as market locations that do not also have government offices. Classifying marketplaces in terms of their proximity to government offices provides an indicator of food demand from salaried workers and perhaps also more local infrastructure. These facilities are located endogenously in response to other factors, so this study does not identify a causal effect of nonfarm activity in rural towns but aims solely to compare the cost of nutritious foods as a potential contributor to disparities between rural towns and more remote rural areas. We hypothesize that more remote areas will have higher prices for the more nutritious foods that are typically more perishable and may therefore require cold storage, only profitable within economies of scale where marketing costs are lower, or in other words, at locations with a higher sales volume. This leads us to believe that the price ratio of more nutritious foods to less nutritious foods would be greater in markets that serve poorer people than in markets that serve richer people. Thus, poorer people pay a higher premium for more nutritious foods relative to basic staples.

The retail prices for staple commodities like rice and maize are readily compared because the products are highly standardized, as are many packaged foods like carbonated drinks. But many vegetables and fruits or other nutritious foods have prices that vary greatly depending on exactly what, when and where the food is sold. A key step towards comparing food costs over space and time is choosing the weights to use in a price index. For this study, we use the least-cost foods that meet nutrient requirements for a healthy and active life at each market in each month, relative to the least-cost staples that provide just enough dietary energy for daily subsistence. As a robustness check, we also use a food-group approach, comparing the average, median, least-cost and second-lowest priced item from each food group at each market every month. Price indexes that track the cost of nutrients and foods within groups are useful because they allow for substitution among foods that contribute the same things to human health. On a nutrient basis, for example, carrots and mangoes might be substitutes in the provision of vitamin A. Within food groups, mangoes and oranges would be substitutes in the category of fruits. Comparing the cost of acquiring nutrients or food groups allows us to measure differences in food environments, in this case to test whether more remote rural markets have higher prices for the nutrients and food groups most associated with long-term health needs.

2. Data

The National Statistical Office (NSO) is the main government department responsible for the collection and dissemination of official statistics including retail food prices in Malawi. NSO headquarters is situated in Zomba district with regional offices in the major urban centres of Blantyre, Lilongwe and Mzuzu. All the offices are staffed with field price collectors[1]. The regional offices are responsible for collecting and entering data into a spreadsheet before sending them to headquarters. The headquarters is responsible for data validation, quality adjustment, aggregation, analysis and dissemination within two weeks of the end of each reference month. The food prices are used to compute monthly CPI, which is released 15 days after the end of each reference month. The data collection process for food prices depends on market location and choice of vendor as well as the product quality, unit of sale and retail environment. This section provides detailed description of how food price observations are made in Malawi, in terms of their exact locations, time of purchase and reference items for each type of food, including how data collectors look for products that may be hard to find or unavailable on a given market day.

2.1 Selection of markets

According to International Monetary Fund (2005), the first CPI in Malawi was compiled in the late 1960's and covered only the cities of Blantyre and Lilongwe. The scope was expanded to cover Mzuzu and Zomba cities during the rebase of 1980, and then rural areas were introduced during the 1990 rebase. The rebases in the 1980 and 1990 were based on Household Expenditure Surveys (HES)[2]. At the end of 2002, the index was rebased to 2000 using the results of the first Integrated Household Survey (IHS)[3] which was conducted in 1997-98. Since 2000, the weights in the CPI are based on the IHS results in which expenditure on consumer goods and services is valued at market purchaser's prices inclusive of trade and transport margins (on goods) and product taxes. So far, there have been six rebases: 1980, 1990, 2000, 2007, 2012, and 2017. The recorded prices are actual market transaction prices with the product specification defined in terms of all the price determining characteristics, as far as feasible, in order to support pricing to constant quality. The IHS has a market survey that facilitates the selection of CPI markets. The survey is a verification exercise of items reported in the consumption expenditure module of the IHS to generate conversion factors, which are specific to each enumeration area (EA). Through this exercise, both the

[1] International Monetary Fund (2005) indicates that there are three regional field price collectors in Blantyre, five in Lilongwe, three in Zomba, and three in the northern region.

[2] HES is a nationally representative survey that collects household expenditures on different kinds of consumer goods and services over a specified period such as a week, month or longer.

[3] IHS is also is a nationally representative survey that collects a wide range of demographic and social data to support Poverty Reduction Programs, as well as expenditure and consumption data by commodity.

selected markets and the commodity basket change from one 5-year period to the next, which takes into consideration the changes in people's tastes and the introduction of new commodities to the market over that period. Thus, food items that people no longer purchase or unavailable on the market are removed from the CPI while new food items are introduced at the time of the rebase.

All the markets in the cities (Blantyre, Lilongwe, Zomba and Mzuzu) are selected to represent urban markets whereas the district level markets are selected to represent rural markets. Urban markets are sub-divided into socio-economic groups, namely: high-income, medium-income, and low-income groups. These groups are based on terciles of the distribution of poverty observed in the IHS data. The selection of rural markets is based on activity level of the market with more active markets selected for inclusion, the size of the market, and the number of EAs the market is serving. Households within an EA are assumed to have the same purchasing behaviour. If the market becomes inactive or the activity level of vendors change during the 5-year data collection period, the vendors are replaced, or the entire market is simply dropped or replaced with a more active market in the same geographic area.

Over the time period we analyze, there are 29 rural markets monitored monthly for the CPI. Seventeen (17) markets are located at the centre of the district, which are referred to "boma market/rural town markets" and twelve (12) markets are located away from the centre of the district, which are referred to "more remote markets" (see figure 1). The boma market market is considered as the main market in the district. Most of the selected more remote markets are allocated along the district main road network, which does not represent the typical rural area situation in those districts. However, this might mean that there are similar price movements between typical more remote markets and the selected more remote markets. Majority of the markets are more active on a specified day of the week, known as 'marketing day'. During the marketing day, farmers from the remotest end of the district sell their produce and buy their necessities such as food items, clothes, groceries and farm inputs. During this time, most of the commodities are available on the market and the prices may be lower than during the normal days, which attract buyers from many ends of the district.

All the rural markets are quite diverse, comprising outlets of large retail chains such as People Trading Centre, large-scale and small-scale permanent retailers, and middle-vendors and farmers. The middle-vendors and farmers operate in an open area whereas retail outlets and permanent vendors operate in stores of different sizes. Agricultural food products are mainly produced by small-scale farmers, some of whom sell their produce to the final consumers while others supply their produce to middle-vendors. Usually, the middle-vendors sell fresh vegetables, fruits and animal-based foods. Conversely, large-scale

and small-scale permanent retailers sell processed foods, groceries, hardware, and clothes. They procure their products from markets within the city and sell them in either boma market or more remote markets at higher prices. As already been indicated, the main distinction between boma and more remote markets is the presence of government offices.

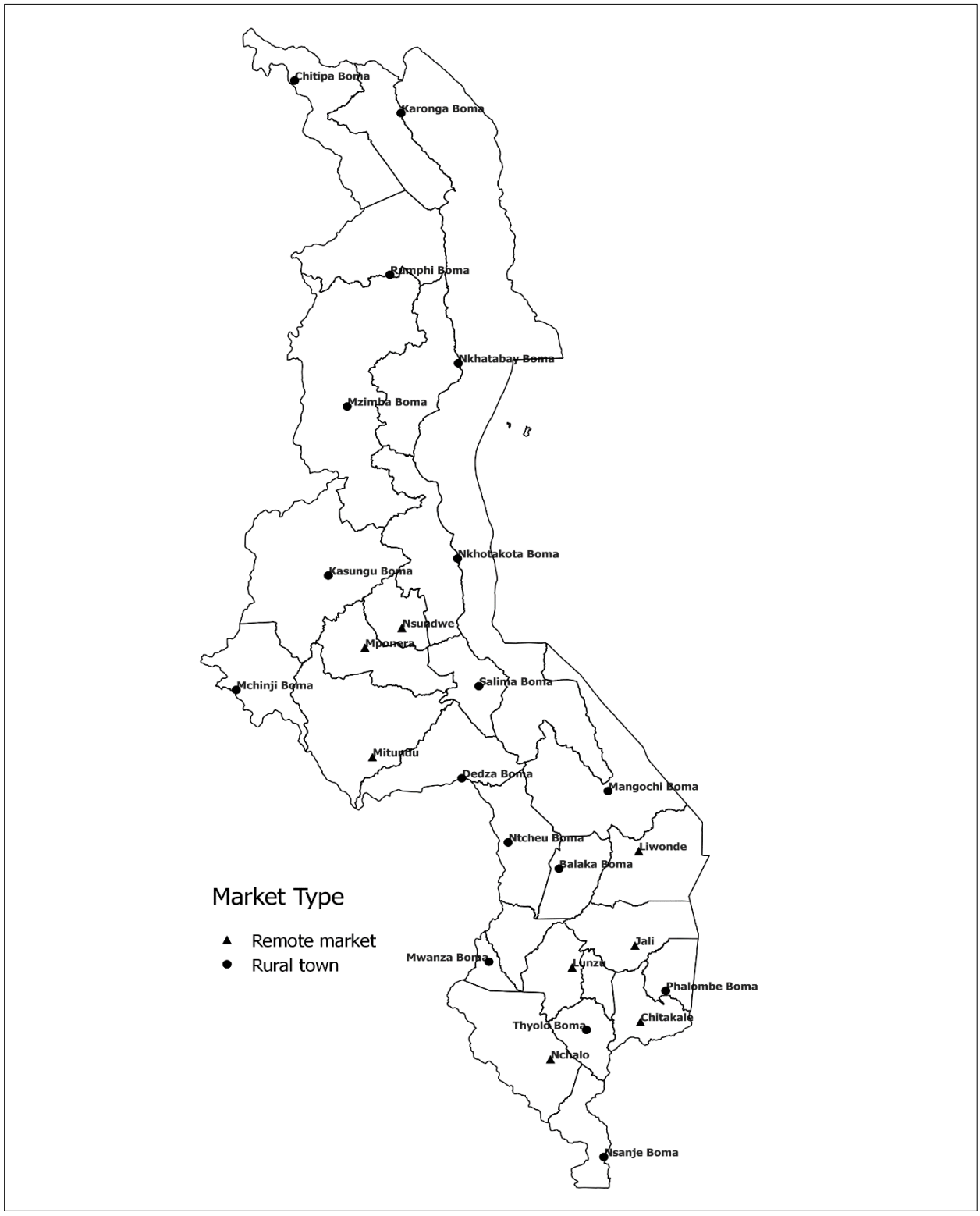

Figure 1: Some of the CPI selected rural markets by type

2.2 Selection of the food items

The consumption expenditure module of the IHS also determines the food items in the CPI food basket. An item is included if it exceeds a threshold of 0.02% of total expenditure. The CPI food basket constitutes about 55 food items. These items are categorized into standardized and non-standardized food items (see table A.1 in the appendix); standardized meaning items whose weights are predetermined by the manufacturer (e.g. 1kg packet of sugar) and non-standardized meaning items whose weights are unknown at the point of purchase (e.g. a pail of maize or a cup of beans). Because the list of food items is predetermined, the objective is usually to select food items that are representative of the larger group of food items within an elementary aggregate.

NSO has specifics for the food items selected for pricing. For animal-based foods, for example, beef has many different cuts such as minced beef, stewing steak or rump steak, each of which can be considered as a different food item, and which can sell at different prices. In addition, beef can also be classified according to whether it is fresh, chilled or frozen, and cross-classified again according to whether it comes from domestic or imported animals, or from animals of different ages or breeds (International Labour Organization *et al.,* 2004). NSO specifies a kilogram of fresh mix-cut for beef, goats and pigs regardless of their breeds and ages. A live local chicken, medium in size is selected for pricing regardless of whether it is a cock or hen. A crate of medium sized eggs is selected for pricing regardless of whether the eggs are from local chickens or hybrids. NSO specifies medium sized fresh chambo[4] and smoke-dried chambo for pricing. Utaka and usipa may either be sun dried or smoked. NSO specifies a heap for sun-dried utaka and usipa for pricing. The specifics for fresh and powdered milk are different. NSO specifies 500 ml packet of fresh milk produced locally by two dairy companies and 400g tin of imported full cream powdered milk, anchor or kerrygold, for pricing. Further, NSO specifies a 500ml bottle of cooling oil refined by a local company, but there are no specifics for refilled cooking oil for pricing.

Fresh vegetables such as pumpkin leaves, Chinese cabbage, mustard leaves and rape are more difficult to price as some vendors might price the number of leaves per bunch while others might price the quantity of leaves their palm can hold (in this case, the vendor might sell the vegetables to different categories of buyers at different prices). Conversely, onions, cucumbers, cabbages, fresh pumpkin, and tomatoes can be priced per unit or per heap while green beans (*zitheba*), okral, and eggplants are priced per heap. Similarly, fruits like bananas may be sold per item or bunch while other fruits such as mangoes, oranges,

[4] Lake Malawi Tilapia, locally known as *chambo.*

pawpaw, guavas, apples (imported) and avocado pears are sold per item. NSO specifies the smallest unit of fresh vegetables and fruits that any consumer can afford for pricing.

Most of the agricultural food products such as maize, beans, pegion peas, dried cowpeas, shelled groundnuts, rice long-grain, potatoes and sweet potatoes are produced from either local or improved varieties. NSO has loose specifications for these foods and recommends procuring the smallest unit any consumer can afford regardless of the variety and size for pricing. This means that NSO does not have the control over the characteristics of these food items being priced in different markets. NSO specifies a 300ml bottle of soft drinks, 500lm bottle of maheu, coarse salt for cooking, tea leaves produced by a specific local company, a 1Kg packet of locally produced white and brown sugar, 60g of gluco power biscuits, 600g of standard loaf of white bread, medium size buns and mandazi for pricing.

2.3 Price collection procedure

The data are collected during the first two weeks of each month using a paper-based questionnaire and the remaining two weeks are used for analysis. The questionnaire list all the food items that are known to be available in the market places across the country with clear specification for each food item. The lists of food items are different for rural and urban markets. This means that price collectors are restricted to collect price data on food items that are printed on the questionnaires. The information about prices from the previous month are also pre-printed on the questionnaires for comparison purposes. The data are collected from retail shops (from very small permanent stalls to multinational chains of stores), and vendors operating in the open air. International Labour Organization *et al.* (2004) indicate that it would be desirable to select the vendors using random sampling techniques with known probabilities of selection, however, it requires comprehensive and up-to-date sampling frame. This would ensure that the sample of vendors is not distorted by subjective factors and would enable calculation of sampling errors. NSO uses purposive selection of vendors because it does not have a sampling frame (*i.e.* a business register) of all the vendors for the monthly CPI survey (International Monetary Fund, 2005). This means that price collectors use their sound judgment at a lower level to select and maintain vendors who are willing to provide the information by virtue of knowledge or experience and the vendors do not have equal chance of participation in the survey. Further, the sample errors and non-responses are not associated with Malawi's CPI survey. However, the retail shops and stores are preselected by NSO based on their activity level and are maintained throughout the reference period. Three stores are preselected per market for pricing certain food items in the CPI basket. This means that the price collector cannot replace the store when it is not operational during the survey day.

Price collectors visit the markets during marketing days, because most of the food items to be priced are available. Figure 2 shows that the entry point for the price collector is to either identify a vendor selling to the final consumer to participate in the monthly survey or revisit a preselected store in the market[5]. The price collector introduces themselves and explain the objective of the survey and price collection procedure to the shopkeeper. If the vendor is willing to participate in the survey, the price collector proceed to price the food items available on the questionnaire that the vendor is selling on the day of the survey. NSO recognises that vendors may sell the same food item at different prices within the same market or the same food item may be sold to different categories of purchasers at different prices. To control for price variations, price collectors purchase three samples of non-standardized food items from three different vendors in the same market. Take the samples back to NSO offices and weigh them to compute the geometric mean price per kg. This ensures that realistic transaction prices are obtained. In the case of standardized food item, the actual prices of the selected item are observed and recorded from three different vendors in the same market.

[5] Prices for raw food products such as maize, vegetables and fruits are collected from vendors while prices for manufactured food items such as cooking oil, sugar, and powdered milk are collected from preselected retail stores.

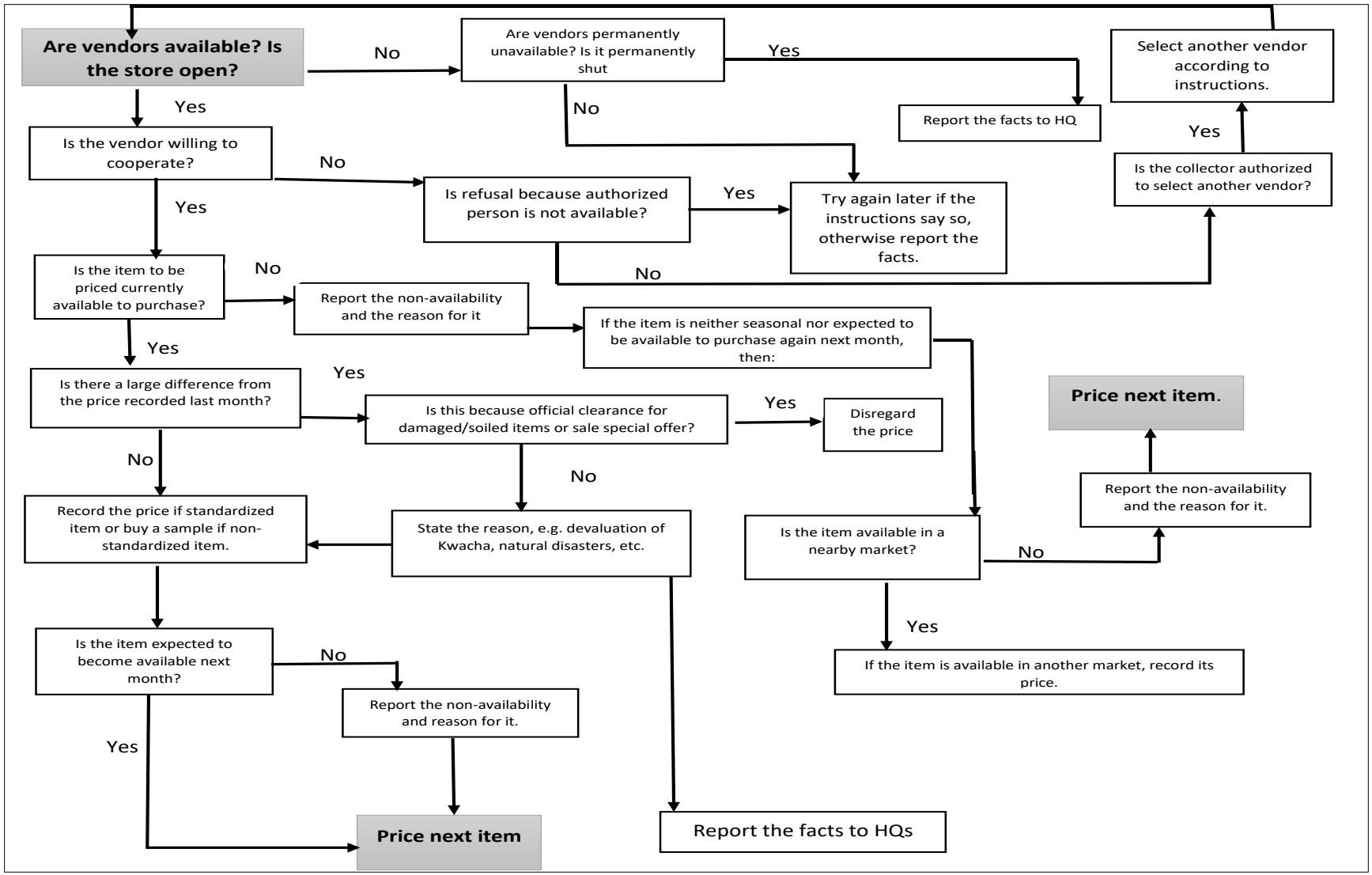

Figure 2: Malawi's price collection procedure from vendors and preselected stores

Source: Chart developed from a version by International Labour Organization *et al.* (2004)

It is not unusual that the food item may not be available in the market due to seasonality or stockouts (*i.e.* temporarily missing during the day of data collection but the food item is restocked during the other days of the reference month). When the food item is not available due to stockouts, its price is either estimated based on its most recent price, the movement of prices of similar food items of comparable quality on the same market or uses the price of that item in a nearby market. The choice of a similar item is made using the same key specifications for the original food item. For example, when 0.5l of cooking oil produced by a specified local company is not available, the collector would price a similar 0.5l of cooking oil produced by another local company available on the market on the survey day. The price collector would record both the previous and the current prices of the similar product and determine the price difference. The price difference is used to estimate the current price of the preselected food item. Thus, if price for 0.5l cooking oil of a similar product increases by MK50 (US$0.07)[6] from the previous month, then the price of the preselected 0.5l cooking oil would be estimated by adding MK50 (US$0.07) to its previous price. However, prices for out-of-season items are not imputed using in-season item price movements. This means that the price series of out-of-season food items will have missing data during the period the food items are off-season. When a product becomes permanently unavailable for consecutive four months, the price collector is required to report the facts to the head office[7]. In this case, the prices for permanently unavailable food item will be missing in a given market until the item is removed from that market during the rebase. Having priced all the items required in that market, the collector can move on to the next market.

International Monetary Fund (2005) note that the prices of perishable food items such as fruits, vegetables, eggs, meat and fresh fish should be collected more frequently, for example on a weekly basis, than monthly in order to yield reliable indicators of month-to-month price movements. International Labour Organization *et al.* (2004) suggest collecting prices for these food items three to six times in a day, including a morning, lunchtime and evening visits. However, due to budget constraint[8], the field price collectors only visit the vendors once every month. To control for price changes due to perishability, the survey team visit the market early in the morning and buy high quality samples. Therefore, the price

[6] 1US$=725 MK as of April 2019.

[7] The item may be permanently unavailable either when vendors no longer intends to stock an item or when producers no longer produce the item.

[8] Most of the markets are located outside the districts the regional offices are located. This requires the survey team to travel to the field a day before the marketing day in order to visit the markets the following morning. This involves Daily Subsistence Allowances for the price collectors, fuel, and money to purchase the required samples for each unstandardized food items.

differences for these foods cannot be attributed to quality deterioration throughout the day. Non-perishable food items are collected at any time of day.

3. Analysis

Our dataset is comprised of the retail prices for 55 food items, collected over 129 months from January 2007 through July 2017, in 29 rural markets. Not all items are available in each market every month, so our final dataset consists of 130,975 individual food prices in 3,701 market-months. Firstly, we test whether on average the observed market prices for each type of food are systematically higher or lower in boma markets versus the more remote markets using OLS regression:

$$P_{ijt} = \beta_0 + \beta_1 Z_{it} + \beta_2 F_i + \beta_4 (Z_{it} * F_i) + \beta_5 X_{it} + \beta_6 M_{it} + \beta_7 Y_{it} + \varepsilon_{it} \quad (1)$$

where P_{ijt} is the retail price of each food item observed in MK/Kg denoted *i* in market *j* at time *t*, Z_{it} is binary variable equal to 1 for boma market market and 0 otherwise, F_i is an indicator equal to 1 for each of the 54 food items other than the first food item, maize grain sold by private traders, as the reference category. The interaction of Z_{it} and F_i, measures whether on average the observed market prices for each type of food items are systematically higher or lower in boma markets versus the most remote markets. X_{it} is an indicator equal to 1 for each of the 28 markets other than the first market, Chitipa Boma, as the reference category which controls for market effects. M_{it} is an indicator equal to 1 for each of the 11 months, January as the reference month and Y_{it} is an indicator equal to 1 for each of the 9 years, 2007 as the reference year. Both M_{it} and Y_{it} control for time effects. The constant is represented by β_0, and $\beta_1 - \beta_7$ are all unknown parameters to estimate while ε_{it} is a random error term.

As a robustness check, we also compare healthy foods to starchy staples using a food-group approach, comparing the average, least-cost, second-lowest and median priced item from each food group at each market every month (note that regression results for the second-least and median-priced food groups are provided in appendices for comparison, table A.2 and A.3). Items within each food group are ranked to identify the least-expensive, the second-least expensive, and the median-priced items for comparison. We use the six food groups classification from the Malawi Ministry of Health and Population: starchy staples, legumes and nuts, animal-sourced foods, vegetables, fruits, and fats and oils (Government of Malawi, 2007).

We also estimate equation 1 with P_{gjt}, food group price index in MK/Kg, as the dependent variable and F_g, an indicator equal to 1 for each of the five food groups other than starchy staples as the reference

group. Similarly, the interaction of Z_{it} and F_g, measures whether prices of the more nutritious items are higher in more remote rural markets than boma markets. To isolate the cost of local retail services from commodity price dynamics and long-distance transport, we use market fixed effects in addition to controlling for the cost of calories from starchy staple foods at each location.

We then focus on the premium paid for nutritious foods relative to starchy staples, and the cost of diets that achieve overall nutrient adequacy (CoNA) relative to simply daily energy (cost of caloric adequacy, or CoCA). To measure nutrient adequacy, we match the food items to their food composition data using primarily the FAO's West African Food Composition Table, supplemented by the USDA's National Nutrient Database where necessary. Our analysis begins by solving a linear optimization for each market in each month, computing the least cost diet comprised of the quantity of each food needed to meet all known nutrient requirements for a healthy and active life. Given that nutrient requirements vary by age, gender and level of physical activity, we calculate these diet cost indicators for a benchmark group of non-pregnant, non-lactating women of reproductive age (19-30), at an active level of physical activity consistent with the energy expenditure required for a rural, agricultural lifestyle. We then compare this cost of nutrient adequacy (CoNA) to the cost of caloric adequacy (CoCA), which constrains the linear optimization by an energy requirement only and therefore computes the cost of day-to-day subsistence using the food item in a quantity that provides sufficient energy at the lowest cost. Formally, our CoNA index is computed for each location (*k*) in every month (*t*) as (Bai *et al.,* 2018):

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

where the objective function ($\Sigma_i p_i q_i$) 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 2,365.17 kcal per day. We use EAR values for each of 21 essential nutrients from the US Institute of Medicine for an adult woman of a standard reference weight of 57 kg, aged 19 to 30 years old. Our CoCA index is computed in the same way, but with only the one constraint for energy intake:

$$\text{min. } C_{jt} = \Sigma_i p_i q_i, \text{ subject to } \Sigma_i n_{ie} q_i = E \qquad (3)$$

Items excluded from analysis at this stage are tea leaves and maheu, because we do not have their food composition data. Finally, we test whether CoNA or CoCA is different between boma markets and more remote markets using OLS regression:

$$C_{it} = \beta_0 + \beta_1 Z_{it} + \beta_2 X_{it} + \beta_3 M_{it} + \beta_4 Y_{it} + \varepsilon_{it} \quad (4)$$

where C_{it} is the cost of nutrient adequacy or the cost of caloric adequacy in another specification (the results for CoCA are presented in table A.4 in the appendix) in 2011 US dollar purchasing-power parity (PPP) prices at time t, Z_{it} is binary variable equal to 1 for boma market and 0 otherwise, X_{it} is an indicator equal to 1 for each of the 28 markets other than the first market, Chitipa Boma, as the reference category which controls for market effects. M_{it} is an indicator equal to 1 for each of the 11 months, January as the reference month and Y_{it} is an indicator equal to 1 for each of the 9 years, 2007 as the reference year. Both M_{it} and Y_{it} control for time effects. The constant is represented by β_0, and $\beta_1 - \beta_4$ are all unknown parameters to estimate while ε_{it} is a random error term.

4. Results and Discussions

4.1 Descriptive Results

Table 1 shows the comparison of retail food prices by type of market (*i.e*. boma market versus more remote market). The results show that the food group price index is higher for staples (MK170/kg), fruits (MK162/kg), and vegetables (MK196/kg) in boma markets than in more remote markets, on average. Conversely, the food group price index is higher for legumes and nuts in the more remote markets (MK356/kg) than in the boma markets (MK347/kg), on average. This is surprising as we would expect the food group price index for legumes and nuts to be lower in more remote markets as they are closer to the producers than in boma markets, however, this might mean that legumes and nuts are oversupplied in the boma markets which keeps the food group price index relatively lower. As a result, competition benefits consumers in boma markets than those in more remote markets based on the production cycle of legumes and nuts.

Table 1: Comparison of retail food prices in MK/Kg by type of market

Food Group	Type of Market				t-statistic
	More remote market		Boma market		
	Mean	Std. Dev	Mean	Std. Dev	
Staples (incl. plantains)	167	150	170	157	-1.5342*
Legumes and nuts	356	194	347	190	2.3259**
Fruits	157	122	162	121	-1.6857**
Animal foods	714	1139	719	1139	-0.3406
Fats and oils	377	278	372	252	0.7466
Vegetables	186	156	196	157	-5.0277***

*, **, *** indicates a statistically significant difference in mean price in MWK between food groups by type of market at the 10%, 5%, and 1% levels, respectively.

Table 2 shows a comparison of the Cost of Nutrient Adequacy (CoNA) and the Cost of Calorie Adequacy (CoCA) by type of market. Over the entire sample, the mean (standard deviation) of CoNA in more remote markets is US$1.48 in 2011 US$ PPP prices (0.81), versus $1.61 in 2011 US$ PPP (0.82) in boma markets. Further, to illustrate the comparison between the CoNA and CoCA by type of market, figure 3 presents binned scatterplots using Stata's -*binscatter*[9]- command, which collapses our 3701 observations into 20 points that preserve the same OLS regression line. This reveals how the cost of nutrient adequacy needed for a healthy life (CoNA) is generally lower in more remote market locations, at each level of cost of caloric adequacy (CoCA). The only exceptions are at very low cost of caloric adequacy where there are few observations. The findings in figure 3 are contrary to our initial hypothesis but are confirmed by a variety of regression results and robustness tests.

[9] Stata's - binscatter- command generates binned scatterplots, which are a convenient way of observing the relationship between two variables, or visualizing OLS regressions (Stepner, 2014). They are especially useful when working with large datasets. Our observations are collapsed to a total of 20 local means for each type of market.

Table 2: Comparison of CoNA and CoCA in US$ by type of market

Index	Type of Market				t-statistic
	More remote markets		Boma markets		
	Mean	Std. Dev	Mean	Std. Dev	
CoNA	1.48	0.807	1.61	0.82	-4.429***
CoCA	0.75	1.29	1.01	2.41	-4.054***

*, **, *** indicates a statistically significant difference in mean price in US$ of CoNA and CoCA by type of market at the 10%, 5%, and 1% levels, respectively.

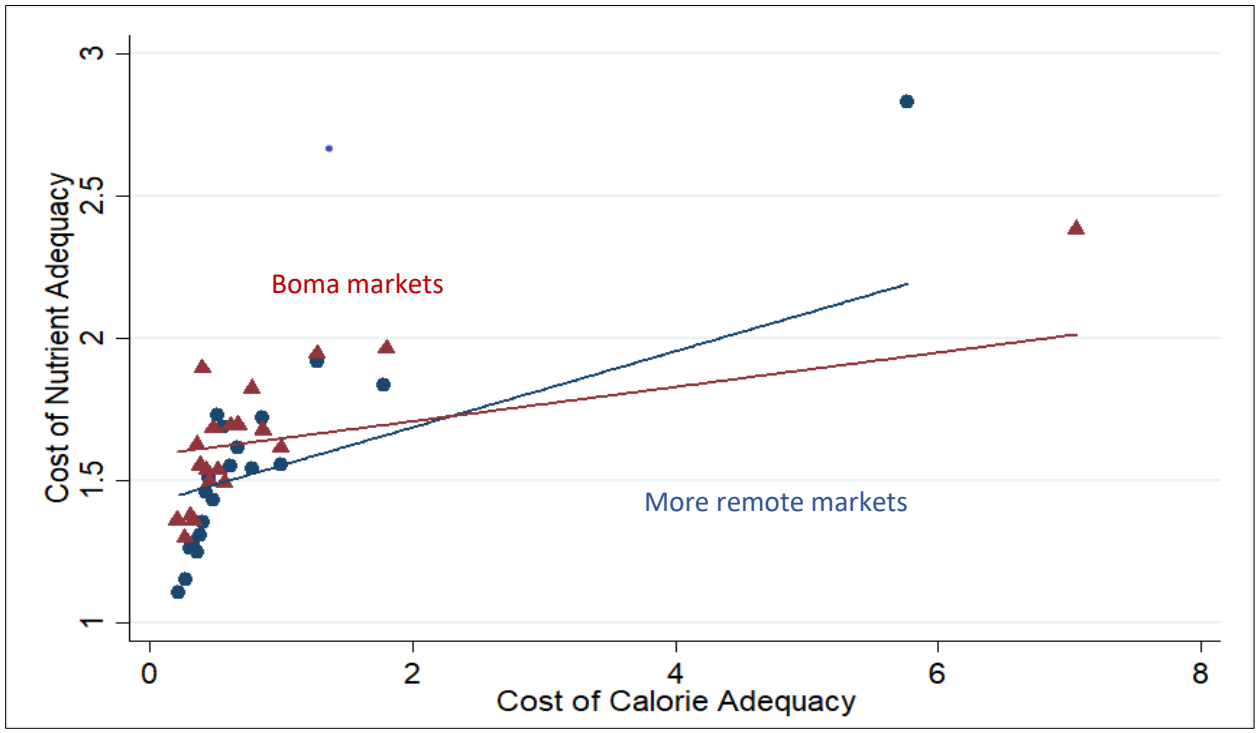

Figure 3: Cost of nutrients versus calories, by market type (n=3,701)

4.2 Empirical Results

Table 3 presents the OLS results of the observed market prices for each type of food. The results show that the food prices for maize grain sold by Agricultural Development and Marketing Corporation (ADMARC, parastatal enterprise), fresh sweet potatoes, fresh pumpkins, fresh Chinese cabbages, fresh eggplants, fresh oranges, fresh pawpaw, fresh guavas, fresh avocado, and small tea leaves are lower than the prices for maize grain sold by private traders. Conversely, the prices for dehulled maize flour, polished rice grain, fresh potatoes, dried white beans, dried brown beans, dried pigeon peas, dried cowpeas,

shelled groundnuts, fresh onions, fresh tomatoes, pumpkin leaves, green beans, fresh okra, fresh bananas, live local chicken, fresh chambo, dried chambo, dried utaka, dried usipa, coarse salt, standard loaf of white bread, white buns, biscuits, mandazi, beef mixed cut, goat mixed cut, pork mixed cut, powdered milk, chicken eggs, cooking oil, refilled cooking oil, white sugar, brown sugar, and banja tea leaves are higher than the prices for maize grain sold by private traders.

The interaction term of type of market and individual food item shows that the prices for maize flour from whole grain, dried chambo, dried utaka, beef mixed cut, powdered milk, and chicken eggs are higher in boma markets than in the more remote markets. These findings suggest that consumers that are served by boma markets pay more for these food items than those that are served by more remote markets, on average. This makes sense given that most people served by more remote markets are food producers whereas higher prices in the boma markets might be driven by higher wages. Conversely, the prices for fresh chambo are lower in boma markets than in more remote markets. This makes sense given that fresh chambo as a highly perishable food item, requires refrigeration facilities which may not be adequately available in more remote markets than in boma markets. As a result, most of the fish catch are transported and sold in boma and urban markets compared to more remote markets.

Table 3: OLS regression results of observed market prices for each type of food by type of market

Dependent variable: Price of food per kg in MK	OLS Estimator	
	Coefficients	**Std. Errors**
Covariates:		
Type of market		
=1 if boma market	15.45	(17.68)
Food item		
=1 if maize is ADMARC	-48.71***	(16.92)
=1 if dehulled maize flour	149.7***	(17.07)
=1 if whole grain maize flour	9.146	(22.28)
=1 if polished rice grain	186.2***	(17.00)
=1 if fresh potatoes	49.92***	(16.48)
=1 if fresh sweet potatoes	-29.88*	(17.12)
=1 if fresh cassava	10.70	(17.59)
=1 if dried white beans	231.5***	(17.04)
=1 if dried brown beans	233.9***	(16.61)
=1 if dried pigeon peas	103.7***	(26.66)
=1 if dried cowpeas	120.1***	(22.97)
=1 if shelled groundnuts	223.0***	(17.06)
=1 if fresh onions	178.6***	(16.42)
=1 if fresh tomatoes	82.42***	(16.42)
=1 if fresh cucumber	-30.12	(30.06)
=1 if fresh pumpkins	-157.8***	(33.77)
=1 if fresh cabbages	-35.15**	(16.66)
=1 if fresh pumpkin leaves	43.66**	(17.17)
=1 if fresh green beans	115.3***	(25.11)
=1 if fresh Chinese cabbages	-72.25***	(21.99)
=1 if fresh okra	77.65***	(17.65)
=1 if fresh rape	4.757	(16.62)
=1 if fresh eggplants	-63.71***	(24.19)
=1 if fresh bananas	48.69***	(17.00)
=1 if fresh oranges	-57.54*	(32.58)
=1 if fresh pawpaw	-100.6***	(37.92)
=1 if fresh guavas	-97.69***	(34.55)
=if fresh avocado	-46.71*	(28.06)
=if fresh mangoes	-22.03	(21.83)
=1 if live local chicken	366.8***	(19.32)
=1 if fresh chambo fish	682.5***	(31.62)
=1 if dried chambo fish	1792.1***	(20.52)
=1 if dried utaka fish	1572.5***	(16.89)
=1 if dried usipa fish	1104.2***	(16.45)
=1 if coarse salt	30.28*	(16.49)
=1 if standard loaf white bread	84.63***	(16.49)
=1 if white buns	439.7***	(17.14)
=1 if biscuits	338.1***	(21.85)
=1 if mandazi	444.1***	(21.67)
=1 if beef mixed cut	230.2***	(16.56)
=1 if goat mixed cut	265.7***	(16.43)

=1 if pork mixed cut	51.09**	(20.01)
=1 if fresh milk	13.05	(17.40)
=1 if powdered milk	177.0***	(19.54)
=1 if chicken eggs	388.3***	(16.64)
=1 if cooking oil	345.0***	(17.01)
=1 if refilled cooking oil	214.7***	(16.59)
=1 if white sugar	200.7***	(17.08)
=1 if brown sugar	199.7***	(16.49)
=1 if banja tea leaves	151.4***	(40.13)
=1 if small tea leaves	-131.8***	(19.94)
=1 if big tea leaves	25.40	(18.14)
=1 if coca cola	5.641	(16.39)
=1 if maheu	-11.86	(25.97)
Type of market type # Food item		
=1 if boma market# =1 if maize is ADMARC	-0.528	(21.99)
=1 is boma marke #=1 if dehulled maize flour	36.92	(22.52)
=1 if boma market#=1 if whole grain maize flour	48.86*	(28.96)
=1 if boma market#=1 if polished rice grain	0.727	(22.06)
=1 if boma market#=1 if fresh potatoes	2.831	(21.46)
=1 if boma market#=1 if fresh sweet potatoes	1.584	(22.30)
=1 if boma market#=1 if fresh cassava	-1.886	(23.20)
=1 if boma market#=1 if dried white beans	-8.269	(22.11)
=1 if boma market#=1 if dried brown beans	-0.457	(21.51)
=1 if boma market#=1 if dried pigeon peas	30.65	(34.50)
=1 if boma market#=1 if dried cowpeas	14.48	(30.24)
=1 if boma market#=1 if shelled groundnuts	1.345	(22.09)
=1 if boma market#=1 if fresh onions	11.20	(21.37)
=1 if boma market#=1 if fresh tomatoes	11.15	(21.36)
=1 if boma market#=1 if fresh cucumber	38.78	(37.59)
=1 if boma market#=1 if fresh pumpkins	-4.951	(44.13)
=1 if boma market#=1 if fresh cabbages	2.910	(21.70)
=1 if boma market#=1 if fresh pumpkin leaves	2.479	(22.20)
=1 if boma market#=1 if fresh green beans	-28.48	(32.25)
=1 if boma market#=1 if fresh Chinese cabbages	1.357	(28.31)
=1 if boma market#=1 if fresh okra	31.43	(22.65)
=1 if boma market#=1 if fresh rape	7.129	(21.63)
=1 if boma market#=1 if fresh eggplants	20.09	(30.77)
=1 if boma market#=1 if fresh bananas	-7.496	(22.00)
=1 if boma market#=1 if fresh oranges	12.10	(40.45)
=1 if boma market#=1 if fresh pawpaw	11.56	(45.36)
=1 if boma market#=1 if fresh guavas	7.801	(44.91)
=1 if boma market#=if fresh avocado	5.788	(36.32)
=1 if boma market#=if fresh mangoes	-8.048	(29.20)
=1 if boma market#=1 if live local chicken	33.51	(25.45)
=1 if boma market#=1 if fresh chambo fish	-152.7***	(42.74)
=1 if boma market#=1 if dried chambo fish	235.8***	(28.22)
=1 if boma market#=1 if dried utaka fish	143.7***	(22.52)
=1 if boma market#=1 if dried usipa fish	17.02	(21.43)

	=1 if boma market#=1 if coarse salt	8.457	(21.46)
	=1 if boma market#=1 if standard loaf white bread	-13.78	(21.50)
	=1 if boma market#=1 if white buns	24.11	(22.62)
	=1 if boma market#=1 if biscuits	2.529	(28.07)
	=1 if boma market#=1 if mandazi	19.27	(27.96)
	=1 if boma market#=1 if beef mixed cut	38.04*	(21.62)
	=1 if boma market#=1 if goat mixed cut	-11.02	(21.55)
	=1 if boma market#=1 if pork mixed cut	-8.071	(26.36)
	=1 if boma market#=1 if fresh milk	5.457	(22.50)
	=1 if boma market#=1 if powdered milk	72.55***	(24.90)
	=1 if boma market#=1 if chicken eggs	96.02***	(21.74)
	=1 if boma market#=1 if cooking oil	0.247	(22.19)
	=1 if boma market#=1 if refilled cooking oil	-14.23	(21.70)
	=1 if boma market#=1 if white sugar	-9.153	(22.33)
	=1 if boma market#=1 if brown sugar	-1.651	(21.45)
	=1 if boma market#=1 if banja tea leaves	29.06	(58.12)
	=1 if boma market#=1 if small tea leaves	4.537	(26.39)
	=1 if boma market#=1 if big tea leaves	6.367	(23.63)
	=1 if boma market#=1 if coca cola	-16.82	(21.61)
	=1 if boma market#=1 if maheu	12.75	(35.99)
Market			
	=1 if Karonga Boma	21.07**	(9.806)
	=1 if Chilumba	43.07***	(9.505)
	=1 if Nkhatabay Boma	33.36***	(9.852)
	=1 if Rumphi Boma	33.19***	(9.821)
	=1 if Ekwendeni	64.36***	(9.484)
	=1 if Mzimba Boma	66.84***	(9.715)
	=1 if Kasungu Boma	11.13	(9.630)
	=1 if Dedza Boma	10.33	(9.672)
	=1 if Salima Boma	18.85*	(9.681)
	=1 if Mitundu	19.15**	(9.347)
	=1 if Nsundwe	28.88***	(9.423)
	=1 if Nsalu	19.99**	(9.744)
	=1 if Mponera	22.65**	(9.417)
	=1 if Mchinji Boma	24.33**	(9.772)
	=1 if Nkhotakota Boma	2.638	(9.765)
	=1 if Jali	28.91***	(9.109)
	=1 if Mangochi Boma	-3.411	(9.583)
	=1 if Liwonde	63.88***	(9.200)
	=1 if Balaka Boma	36.27***	(9.615)
	=1 if Ntcheu Boma	15.23	(9.701)
	=1 if Phalombe Boma	-0.298	(9.961)
	=1 if Chitakale	61.78***	(8.964)
	=1 if Thyolo Boma	49.08***	(9.405)
	=1 if Nchalo	41.06***	(9.008)
	=1 if Lunzu	70.36***	(8.908)
	=1 if Mwanza Boma	30.64***	(9.507)
	=1 if Nsanje Boma	33.03***	(9.622)

Month			
	=1 if February	0.106	(5.976)
	=1 if March	-6.247	(5.950)
	=1 if April	6.794	(5.950)
	=1 if May	13.08**	(5.966)
	=1 if June	15.72***	(5.973)
	=1 if July	27.15***	(5.986)
	=1 if August	24.67***	(6.062)
	=1 if September	28.50***	(6.181)
	=1 if October	24.32***	(6.170)
	=1 if November	33.45***	(6.159)
	=1 if December	40.20***	(6.171)
Year			
	2008	34.58***	(6.138)
	2009	48.60***	(6.115)
	2010	63.16***	(6.101)
	2011	76.15***	(6.089)
	2012	145.2***	(6.145)
	2013	255.4***	(5.805)
	2014	326.7***	(5.781)
	2015	364.5***	(5.788)
	2016	446.5***	(5.821)
	2017	525.3***	(6.525)
Constant		-141.8***	(14.38)

Note: N= 130975; ***, **, * indicates that the corresponding coefficient estimates are statistically significant at the 1%, 5%, and 10% level respectively.

Table 4 shows regression results of premiums paid for nutrient-dense food groups relative to starchy staples. The results show that the food group price index is lower in boma markets by MK40.62/Kg than in more remote markets, on average. This finding suggests that consumers that are served by more remote markets pay more for different types of food groups than those that are served by boma markets. The results further indicate that the food group price index for fruits (MK-45.75/Kg) is lower than for staples whereas the food group price index for animal foods (MK547.80/Kg), legumes and nuts (MK166.20/Kg), and fats and oils (MK233.40/Kg) are higher than those for staples, on average. This suggests that fruits are least expensive source of food whereas animal food, legumes and nuts, and fats and oils are most expensive source of food compared to staples in Malawi.

Table 4: premiums paid for nutrient-dense food groups relative to starchy staples

Dependent variable: average price of each item in each food group per kg in MK	OLS Estimator	
	Coefficients	**Std. Errors**
Covariates:		
Type of Market		
=1 if boma market	-40.62***	(15.50)
Malawi's food group		
=1 if Vegetables	-0.416	(8.305)
=1 if Fruits	-45.75***	(12.64)
=1 if Animal foods	547.8***	(8.016)
=1 if Legumes and nuts	166.2***	(10.27)
=1 if Fats and oils	233.4***	(12.67)
Market type # Food group		
=1 if boma market# =1 if Vegetables	3.303	(10.81)
=1 if boma market# =1 if Fruits	-8.634	(16.33)
=1 if boma market# =1 if Animal foods	-1.873	(10.54)
=1 if boma market# =1 if Legumes & nuts	-3.867	(13.36)
=1 if boma market# =1 if Fats & oils	-12.88	(16.64)
Market		
=1 if Karonga Boma	21.46	(14.41)
=1 if Chilumba	-11.03	(14.10)
=1 if Nkhatabay Boma	89.95***	(14.50)
=1 if Rumphi Boma	43.90***	(14.51)
=1 if Ekwendeni	27.71**	(13.99)
=1 if Mzimba Boma	112.8***	(14.28)
=1 if Kasungu Boma	49.14***	(14.08)
=1 if Dedza Boma	61.79***	(14.15)
=1 if Salima Boma	61.38***	(14.17)
=1 if Mitundu	-4.777	(13.83)
=1 if Nsundwe	1.689	(13.86)
=1 if Nsalu	5.564	(14.47)
=1 if Mponera	5.492	(13.93)
=1 if Mchinji Boma	27.75*	(14.34)
=1 if Nkhotakota Boma	51.22***	(14.37)
=1 if Jali	37.05***	(13.52)
=1 if Mangochi Boma	78.82***	(14.11)
=1 if Liwonde	61.13***	(13.71)
=1 if Balaka Boma	105.5***	(14.16)
=1 if Ntcheu Boma	76.39***	(14.38)
=1 if Phalombe Boma	91.44***	(14.73)
=1 if Chitakale	59.78***	(13.26)
=1 if Thyolo Boma	135.2***	(13.83)
=1 if Nchalo	31.72**	(13.34)
=1 if Lunzu	77.34***	(13.20)
=1 if Mwanza Boma	105.9***	(14.00)
=1 if Nsanje Boma	91.15***	(14.12)
Month		
=1 if February	1.419	(8.859)

	=1 if March	-9.948	(8.813)
	=1 if April	10.28	(8.814)
	=1 if May	16.43*	(8.844)
	=1 if June	16.98*	(8.860)
	=1 if July	33.68***	(8.884)
	=1 if August	28.97***	(8.994)
	=1 if September	30.43***	(9.172)
	=1 if October	24.50***	(9.151)
	=1 if November	34.27***	(9.132)
	=1 if December	40.21***	(9.154)
Year			
	=1 if 2008	25.46***	(9.066)
	=1 if 2009	37.62***	(9.041)
	=1 if 2010	52.85***	(9.004)
	=1 if 2011	65.86***	(8.995)
	=1 if 2012	138.8***	(9.096)
	=1 if 2013	217.1***	(8.544)
	=1 if 2014	304.2***	(8.477)
	=1 if 2015	340.1***	(8.493)
	=1 if 2016	416.9***	(8.531)
	=1 if 2017	503.4***	(9.602)
Constant		-69.00***	(13.79)

Note: N= 102515; ***, **, * indicates that the corresponding coefficient estimates are statistically significant at the 1%, 5%, and 10% level respectively.

Table 5 shows that the prices for the least-expensive item in each food group relative to the least-expensive starchy staples. The results indicate that the costs of the least-expensive food item in legumes and nuts (MK61/Kg) and fats and oils (MK99.20/Kg) are higher than those in staples, on average. Further, the costs of the least-expensive food item in animal foods are higher by MK24.36/Kg in boma markets than in more remote markets, on average. Conversely, the costs of the least-expensive food item in fats and oils are lower by MK30.16/Kg in boma markets than in more remote markets, on average. The lower price for least-expensive food item in fats and oils could be attributed to the cost of transporting fats and oils from the cities, where they are produced, which may be higher for more remote markets than boma markets.

Table 5: The cost of the least-expensive item in each food group relative to the least-expensive starchy staples

Dependent variable: least-expensive item in each food group per kg in MK	OLS Estimator	
	Coefficients	**Std. Errors**
Covariates:		
Type of Market		
=1 if boma market	-6.545	(9.676)
Malawi's food group		
=1 if Vegetables	-10.19	(7.526)
=1 if Fruits	2.354	(8.162)
=1 if Animal foods	5.141	(7.873)
=1 if Legumes and nuts	61.00***	(8.896)
=1 if Fats and oils	99.20***	(9.730)
Market type # Food group		
=1 if boma market# =1 if Vegetables	3.420	(9.855)
=1 if boma market# =1 if Fruits	1.648	(10.23)
=1 if boma market# =1 if Animal foods	24.36**	(10.92)
=1 if boma market# =1 if Legumes & nuts	13.31	(10.75)
=1 if boma market# =1 if Fats & oils	-30.16***	(11.48)
Market		
=1 if Karonga Boma	4.728	(14.66)
=1 if Chilumba	-26.52*	(15.97)
=1 if Nkhatabay Boma	0.692	(33.24)
=1 if Rumphi Boma	0.234	(13.20)
=1 if Ekwendeni	5.200	(13.86)
=1 if Mzimba Boma	6.072	(10.25)
=1 if Kasungu Boma	-62.38***	(7.323)
=1 if Dedza Boma	18.63**	(8.385)
=1 if Salima Boma	-42.51***	(9.469)
=1 if Mitundu	-29.40***	(7.755)
=1 if Nsundwe	-16.61*	(9.953)
=1 if Nsalu	-50.76***	(9.904)
=1 if Mponera	6.364	(13.33)
=1 if Mchinji Boma	-45.49***	(7.881)
=1 if Nkhotakota Boma	-35.08**	(14.88)
=1 if Jali		
=1 if Mangochi Boma	15.37	(24.15)
=1 if Liwonde	-7.015	(9.239)
=1 if Balaka Boma	-12.01	(8.433)
=1 if Ntcheu Boma	-14.31*	(8.535)
=1 if Phalombe Boma	11.62	(9.726)
=1 if Chitakale	-14.52	(9.675)
=1 if Thyolo Boma	6.014	(13.08)
=1 if Nchalo	-34.31**	(15.48)
=1 if Lunzu	-2.583	(8.489)
=1 if Mwanza Boma	29.06**	(12.87)
=1 if Nsanje Boma	-3.075	(7.232)
Month		

	=1 if February	4.835	(6.115)
	=1 if March	2.723	(6.155)
	=1 if April	0.663	(6.382)
	=1 if May	0.409	(6.329)
	=1 if June	2.980	(6.258)
	=1 if July	11.44*	(6.263)
	=1 if August	9.034	(6.179)
	=1 if September	13.49**	(6.341)
	=1 if October	14.19**	(6.265)
	=1 if November	15.54**	(6.213)
	=1 if December	16.41***	(6.161)
Year			
	=1 if 2008	13.27**	(6.453)
	=1 if 2009	16.73**	(6.569)
	=1 if 2010	21.15***	(6.411)
	=1 if 2011	13.70**	(6.489)
	=1 if 2012	26.63***	(6.397)
	=1 if 2013	27.34***	(6.309)
	=1 if 2014	29.15***	(6.445)
	=1 if 2015	31.99***	(6.585)
	=1 if 2016	31.86***	(6.391)
	=1 if 2017	47.13***	(6.986)
Constant		13.01	(9.425)

Note: N=637; ***, **, * indicates that the corresponding coefficient estimates are statistically significant at the 1%, 5%, and 10% level respectively.

Table 6 shows that controlling for market effects, CoNA is higher by US$0.28 in 2011 US$ PPP ($p<0.001$) in the boma markets. This finding suggests that the costs of nutrient-dense foods are higher in the boma markets than in the more remote rural markets, on average. This means that it is relatively expensive for consumers served by boma markets to consume nutrient-dense foods than consumers that are served by the more remote markets, on average. However, the cost of subsistence (CoCA) (table A.4 in the appendix), and the price ratio of more nutritious foods (CoNA) to less nutritious foods (CoCA) (table A.5 in the appendix) are not significantly different between the two types of markets.

Table 6: Relationship between CoNA index and type of the market

Dependent variable: Cost of Nutrient Adequacy index	OLS Estimator	
	Coefficients	**Std. Errors**
Covariates:		
Type of market		
=1 if boma market	0.277***	(0.101)
Market		
=1 if Chilumba	0.559***	(0.101)
=1 if Chitakale	-0.0562	(0.0996)
=1 if Chitipa Boma	-0.364***	(0.105)
=1 if Dedza Boma	-0.372***	(0.103)
=1 if Ekwendeni	-0.0987	(0.0987)
=1 if Jali	-0.0293	(0.101)
=1 if Karonga Boma	-0.423***	(0.105)
=1 if Kasungu Boma	-0.317***	(0.102)
=1 if Liwonde	0.230**	(0.0973)
=1 if Lunzu	0.0529	(0.0987)
=1 if Mangochi Boma	-0.241**	(0.105)
=1 if Mbulumbuzi	-0.145	(0.101)
=1 if Mchinji Boma	0.0491	(0.104)
=1 if Mitundu	-0.279***	(0.101)
=1 if Mponera	0.0113	(0.102)
=1 if Mwanza Boma	0.00383*	(0.103)
=1 if Mzimba Boma	-0.168	(0.101)
=1 if Nchalo	0.211**	(0.0961)
=1 if Nkhatabay Boma	-0.318***	(0.103)
=1 if Nkhotakota Boma	-0.00184	(0.104)
=1 if Nsalu	-0.291***	(0.0961)
=1 if Nsanje Boma	-0.263***	(0.102)
=1 if Ntcheu Boma	-0.396***	(0.101)
=1 if Phalombe Boma	-0.101	(0.103)
=1 if Rumphi Boma	0.107	(0.102)
=1 if Salima Boma	0.530***	(0.106)
=1 if Thyolo Boma	0.0509	(0.102)
Month		
=1 if February	0.00874	(0.0635)
=1 if March	-0.0938	(0.0644)
=1 if April	-0.0619	(0.0639)
=1 if May	-0.0575	(0.0635)
=1 if June	-0.0901	(0.0641)
=1 if July	-0.130**	(0.0639)
=1 if August	-0.115*	(0.0639)
=1 if September	-0.0860	(0.0658)
=1 if October	-0.0293	(0.0657)
=1 if November	0.0301	(0.0658)
=1 if December	0.150**	(0.0654)
Year		
=1 if 2008	0.455***	(0.0612)

	=1 if 2009	0.484***	(0.0614)
	=1 if 2010	0.527***	(0.0612)
	=1 if 2011	0.268***	(0.0613)
	=1 if 2012	0.527***	(0.0614)
	=1 if 2013	0.679***	(0.0610)
	=1 if 2014	0.411***	(0.0612)
	=1 if 2015	0.300***	(0.0612)
	=1 if 2016	0.330***	(0.0627)
	=1 if 2017	0.213***	(0.0671)
Constant		1.123***	(0.0904)

Note: N=3297; ***, **, * indicates that the corresponding coefficient estimates are statistically significant at the 1%, 5%, and 10% level respectively.

Conclusions

Using the retail prices for 55 food items, collected over 129 months from January 2007 through July 2017 in 29 rural markets, this study provides a novel test of price differences over the entire mix of foods needed for nutrient adequacy, relative to the cost of subsistence from its cheapest source, comparing more remote versus boma rural markets in Malawi. Specifically, we estimate whether on average the retail prices for each food item are systematically higher or lower in boma markets versus the most remote markets using OLS regression. Using a food-group approach within the OLS regression framework, we compare healthy foods to starchy staples, ranking items within each category to identify the price of the least-expensive, second-least expensive, and the median-priced item within each group for comparison. Then we focus the analysis on the premium paid for nutritious foods relative to starchy staples, and the cost of diets that achieve overall nutrient adequacy (CoNA) relative to just daily energy (cost of caloric adequacy, or CoCA), using a linear programming approach. Finally, we estimate whether CoNA or CoCA is different between boma markets and more remote markets using OLS regression.

Our results indicate that prices for food items such as maize flour from whole grain, dried chambo, dried utaka, beef mixed cut, powdered milk, and chicken eggs are higher in boma markets than in the more remote markets whereas the price for fresh chambo are lower in boma markets than in more remote markets. Further, the food group price index is lower in boma markets by MK40.62/Kg than in more remote markets, on average. This finding suggests that consumers that are served by more remote markets pay more for different types of food groups than those that are served by boma markets. The costs of the least-expensive food item in animal foods are higher by MK24.36/Kg in boma markets than in more remote markets whereas the costs of the least-expensive food item in fats and oils are lower by MK30.16/Kg in boma markets than in more remote markets, on average. Controlling for market, CoNA is

higher by US$0.28 in 2011 US$ PPP ($p<0.001$) in the boma markets. This finding suggests that the costs of nutrient-dense foods are higher in the boma markets than in the more remote rural markets, on average. Given that consumers served by most remote markets are among the poorest while those served by the boma markets (rural towns) tend to be middle income, this finding suggests that middle-income consumers are worse off than poor consumers in accessing nutrient-dense foods that meet their long-term health needs in Malawi. Therefore, our results demonstrate that lower diet quality in more remote areas cannot be explained by systematically lower prices in those markets. Reducing prices even further might be helpful, but our results suggest that other factors, such as household income and purchasing power, time constraints for caregivers, and lower levels of education or nutrition knowledge are more likely to explain the consumption of suboptimal diets.

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Appendix

Table A.1: Categorization of food items into standardized and non-standardized groups

Food Group	***Food Number***	***Food Item***	***Category***
Staple foods	*1*	*Maize_Grain_kg*	*Unstandardized*
	2	*Maize_Grain_ Admarc_kg*	*Standardized*
	3	*Maize_flour_ Woyera_kg*	*Unstandardized*
	4	*Maize_flour_Mgaiwa_kg*	*Unstandardized*
	5	*Rice_grain_kg*	*Unstandardized*
	6	*Bread_White_stardand_loaf (700g)*	*Standardized*
	7	*Potatoes_Irish_kg*	*Unstandardized*
	8	*Potatoes_Sweet_kg*	*Unstandardized*
	9	*Cassava_Fresh_kg*	*Unstandardized*
	10	*Buns_white*	*Unstandardized*
	11	*Mandazi*	*Unstandardized*
Legumes and nuts	*12*	*Beans_White_Dried_kg*	*Unstandardized*
	13	*Beans_Brown_Dried_kg*	*Unstandardized*
	14	*Pegionpeas_Nandolo_Dried_kg*	*Unstandardized*
	15	*Cowpeas_Nkhobwe_Dried_kg*	*Unstandardized*
	16	*Groundnuts_Shelled_kg*	*Unstandardized*
Vegetables	*17*	*Onions_Fresh_kg*	*Unstandardized*
	18	*Tomatoes_Fresh_kg*	*Unstandardized*
	19	*Cucumber_Fresh_kg*	*Unstandardized*
	20	*Pumpkin_Fresh_kg*	*Unstandardized*
	21	*Cabbage_Fresh_kg*	*Unstandardized*
	22	*Nkhwani_Fresh_kg*	*Unstandardized*
	23	*Green_beans_Zitheba_Fresh_kg*	*Unstandardized*
	24	*Chinese_cabbage_Fresh_kg*	*Unstandardized*
	25	*Okra_Lobala_Fresh_kg*	*Unstandardized*
	26	*Tanapusi_Fresh-kg*	*Unstandardized*
	27	*Eggplant_Fresh_kg*	*Unstandardized*
Fruits	*28*	*Banana_Fresh_kg*	*Unstandardized*
	29	*Oranges_Fresh_kg*	*Unstandardized*
	30	*Papaya_Fresh_kg*	*Unstandardized*
	31	*Guava_Fresh_kg*	*Unstandardized*
	32	*Avocado_Fresh_kg*	*Unstandardized*
	33	*Mangoes_Maboloma_Fresh_kg*	*Unstandardized*
Animal foods	*34*	*Chicken_Live (local type)*	*Unstandardized*
	35	*Beef_Ration_kg*	*Standardized*
	36	*Goat_meat_kg*	*Standardized*
	37	*Pork_kg*	*Standardized*

	38	*Chicken_Eggs_unit (medium size)*	*Standardized*
	39	*Chambo_Dry_kg*	*Unstandardized*
	40	*Utaka_Dry_kg*	*Unstandardized*
	41	*Usipa_sun_Dried_kg*	*Unstandardized*
	42	*Chambo_Fresh_kg*	*Unstandardized*
	43	*Milk_fresh_500ml*	*Standardized*
	44	*Milk_powdered_500g*	*Standardized*
Oils and Fats	*45*	*Cooking_Oil_0.5l*	*Standardized*
	46	*Cooking_Oil_refill_0.5l*	*Unstandardized*
Other Food	*47*	*Banja_tea_250g*	*Standardized*
	48	*Tea_leaves_25g*	*Standardized*
	49	*Tea_leaves_250g*	*Standardized*
	50	*Salt_Coarse_kg*	*Unstandardized*
	51	*Cocacola_300ml*	*Standardized*
	52	*Maheu_500ml*	*Standardized*
	53	*Sugar_White_kg*	*Standardized*
	54	*Sugar_Brown_kg*	*Standardized*
	55	*Biscuits_item*	*Standardized*

Table A.2: Cost of the 2nd-least expensive item in each food group relative to the 2nd-least expensive starchy staples

Dependent variable: second-least expensive item in each food group per kg in MK	OLS Estimator	
	Coefficients	**Std. Errors**
Covariates:		
Type of Market		
=1 if boma market	22.69**	(10.31)
Malawi's food group		
=1 if Vegetables	-5.060	(9.360)
=1 if Fruits	3.822	(9.798)
=1 if Animal foods	0.964	(10.83)
=1 if Legumes and nuts	81.11***	(9.705)
=1 if Fats and oils	87.55***	(9.848)
Market type # Food group		
=1 if boma market# =1 if Vegetables	9.789	(12.53)
=1 if boma market# =1 if Fruits	5.968	(12.19)
=1 if boma market# =1 if Animal foods	8.070	(13.46)
=1 if boma market# =1 if Legumes & nuts	-0.785	(12.07)
=1 if boma market# =1 if Fats & oils	20.06*	(11.93)
Market		
=1 if Karonga Boma	-8.881	(17.14)
=1 if Chilumba	11.56	(10.94)
=1 if Nkhatabay Boma	13.37	(13.52)
=1 if Rumphi Boma	-3.721	(23.62)
=1 if Ekwendeni	1.513	(14.24)
=1 if Mzimba Boma	-19.37	(18.78)
=1 if Kasungu Boma	-69.94***	(8.530)
=1 if Dedza Boma	-20.35**	(8.746)
=1 if Salima Boma	-71.64***	(10.44)
=1 if Mitundu	-31.14***	(10.68)
=1 if Nsundwe	0.753	(11.60)
=1 if Nsalu	-53.63***	(12.77)
=1 if Mponera	22.40**	(11.15)
=1 if Mchinji Boma	-36.79***	(8.729)
=1 if Nkhotakota Boma	-18.63	(11.96)
=1 if Jali	-29.01	(39.93)
=1 if Mangochi Boma	-61.49	(40.20)
=1 if Liwonde	4.599	(13.94)
=1 if Balaka Boma	-15.37	(10.38)
=1 if Ntcheu Boma	-21.99**	(8.981)
=1 if Phalombe Boma	-20.31	(12.62)
=1 if Chitakale	14.11	(10.69)
=1 if Thyolo Boma	-15.36	(13.44)
=1 if Nchalo	15.04	(15.78)
=1 if Lunzu	27.60**	(12.14)
=1 if Mwanza Boma	-14.53	(12.96)
=1 if Nsanje Boma	-22.11***	(8.132)

Month			
	=1 if February	-1.813	(7.548)
	=1 if March	-1.362	(7.555)
	=1 if April	-8.744	(7.961)
	=1 if May	0.971	(7.773)
	=1 if June	0.419	(7.689)
	=1 if July	0.0285	(7.642)
	=1 if August	5.526	(7.522)
	=1 if September	9.713	(7.590)
	=1 if October	5.119	(7.883)
	=1 if November	9.878	(7.818)
	=1 if December	26.52***	(7.558)
Year			
	=1 if 2008	16.15**	(7.773)
	=1 if 2009	13.29*	(8.027)
	=1 if 2010	12.30	(7.608)
	=1 if 2011	10.07	(8.051)
	=1 if 2012	48.68***	(7.855)
	=1 if 2013	33.14***	(7.851)
	=1 if 2014	41.37***	(8.214)
	=1 if 2015	49.58***	(8.060)
	=1 if 2016	40.76***	(8.086)
	=1 if 2017	68.76***	(8.969)
Constant		1.604	(11.39)

Note: N=614; ***, **, * indicates that the corresponding coefficient estimates are statistically significant at the 1%, 5%, and 10% level respectively.

Table A.3: Cost of median-priced item in each food group relative to the median-priced starchy staples

Dependent variable: median-priced item in each food group per kg in MK	OLS Estimator	
	Coefficients	**Std. Errors**
Covariates:		
Type of Market		
=1 if boma market	-0.591	(1.532)
Malawi's food group		
=1 if Vegetables	17.97***	(0.832)
=1 if Fruits	-1.092	(0.967)
=1 if Animal foods	239.0***	(0.832)
=1 if Legumes and nuts	194.7***	(1.021)
=1 if Fats and oils	230.2***	(1.416)
Market type # Food group		
=1 if boma market# =1 if Vegetables	0.116	(1.086)
=1 if boma market# =1 if Fruits	0.206	(1.263)
=1 if boma market# =1 if Animal foods	-0.0892	(1.086)
=1 if boma market# =1 if Legumes & nuts	0.250	(1.333)
=1 if boma market# =1 if Fats & oils	0.217	(1.848)
Market		
=1 if Karonga Boma	0.672	(1.335)
=1 if Chilumba	5.63e-10	(1.340)
=1 if Nkhatabay Boma	0.672	(1.335)
=1 if Rumphi Boma	0.672	(1.335)
=1 if Ekwendeni	0.156	(1.338)
=1 if Mzimba Boma	0.672	(1.335)
=1 if Kasungu Boma	0.672	(1.335)
=1 if Dedza Boma	0.672	(1.335)
=1 if Salima Boma	0.672	(1.335)
=1 if Mitundu	0.156	(1.338)
=1 if Nsundwe	0.156	(1.338)
=1 if Nsalu	0.156	(1.338)
=1 if Mponera	5.63e-10	(1.340)
=1 if Mchinji Boma	0.516	(1.338)
=1 if Nkhotakota Boma	0.516	(1.338)
=1 if Jali	0.156	(1.338)
=1 if Mangochi Boma	0.672	(1.335)
=1 if Liwonde	0.156	(1.338)
=1 if Balaka Boma	0.672	(1.335)
=1 if Ntcheu Boma	0.672	(1.335)
=1 if Phalombe Boma	0.672	(1.335)
=1 if Chitakale	5.63e-10	(1.340)
=1 if Thyolo Boma	0.516	(1.338)
=1 if Nchalo	5.63e-10	(1.340)
=1 if Lunzu	5.63e-10	(1.340)
=1 if Mwanza Boma	0.516	(1.338)
=1 if Nsanje Boma	0.516	(1.338)
Month		
=1 if February	-0.635	(0.846)

	=1 if March	-4.239***	(0.846)
	=1 if April	-4.144***	(0.846)
	=1 if May	-2.055**	(0.846)
	=1 if June	1.509*	(0.846)
	=1 if July	6.525***	(0.846)
	=1 if August	7.212***	(0.854)
	=1 if September	7.271***	(0.869)
	=1 if October	4.642***	(0.869)
	=1 if November	11.33***	(0.869)
	=1 if December	13.83***	(0.869)
Year			
	=1 if 2008	37.70***	(0.810)
	=1 if 2009	55.25***	(0.810)
	=1 if 2010	63.39***	(0.810)
	=1 if 2011	75.67***	(0.810)
	=1 if 2012	92.22***	(0.810)
	=1 if 2013	87.97***	(0.810)
	=1 if 2014	119.7***	(0.810)
	=1 if 2015	140.4***	(0.810)
	=1 if 2016	157.0***	(0.810)
	=1 if 2017	195.7***	(0.927)
Constant		30.11***	(1.360)

Note: N=159143; ***, **, * indicates that the corresponding coefficient estimates are statistically significant at the 1%, 5%, and 10% level respectively.

Table A.4: Relationship between CoCA index and type of the market

Dependent variable: Cost of Calorie Adequacy index	OLS Estimator	
	Coefficients	**Std. Errors**
Covariates:		
Type of market		
=1 if boma market	-0.269	(0.266)
Market		
=1 if Chilumba	-0.115	(0.265)
=1 if Chitakale	-0.372	(0.267)
=1 if Chitipa Boma	-0.0501	(0.263)
=1 if Dedza Boma	-0.0980	(0.256)
=1 if Ekwendeni	-0.406	(0.264)
=1 if Jali	-0.192	(0.270)
=1 if Karonga Boma	-0.101	(0.258)
=1 if Kasungu Boma	-0.204	(0.261)
=1 if Liwonde	-0.213	(0.270)
=1 if Lunzu	-0.415	(0.272)
=1 if Mangochi Boma	0.00960	(0.260)
=1 if Mbulumbuzi	-0.459*	(0.266)
=1 if Mchinji Boma	-0.190	(0.259)
=1 if Mitundu	-0.410	(0.272)
=1 if Mponera	-0.387	(0.270)
=1 if Mwanza Boma	0.218	(0.256)
=1 if Mzimba Boma	0.0442	(0.262)
=1 if Nchalo	0.168	(0.269)
=1 if Nkhatabay Boma	0.538**	(0.257)
=1 if Nkhotakota Boma	0.788***	(0.261)
=1 if Nsalu	0.264	(0.287)
=1 if Nsanje Boma	0.399	(0.272)
=1 if Ntcheu Boma	0.664**	(0.267)
=1 if Phalombe Boma	0.936***	(0.266)
=1 if Rumphi Boma	1.041***	(0.263)
=1 if Salima Boma	1.067***	(0.265)
=1 if Thyolo Boma	0.447*	(0.262)
Month		
=1 if February	0.196	(0.167)
=1 if March	0.0112	(0.166)
=1 if April	-0.231	(0.169)
=1 if May	-0.163	(0.168)
=1 if June	-0.0881	(0.169)
=1 if July	0.117	(0.166)
=1 if August	-0.0113	(0.169)
=1 if September	-0.0150	(0.170)
=1 if October	-0.155	(0.171)
=1 if November	0.00878	(0.170)
=1 if December	0.125	(0.170)
Year		
=1 if 2008	0.0879	(0.185)

	=1 if 2009	0.110	(0.185)
	=1 if 2010	0.0537	(0.186)
	=1 if 2011	-0.348*	(0.185)
	=1 if 2012	-0.0685	(0.184)
	=1 if 2013	-0.0659	(0.183)
	=1 if 2014	-0.267	(0.181)
	=1 if 2015	-0.300	(0.182)
	=1 if 2016	-0.0858	(0.188)
	=1 if 2017	-0.0325	(0.197)
Constant		1.076***	(0.269)

Note: N=3279; ***, **, * indicates that the corresponding coefficient estimates are statistically significant at the 1%, 5%, and 10% level respectively.

Table A.5: Relationship between CoNA to CoCA ratio and type of the market

Dependent variable: CoNA to CoCA ratio	OLS Estimator	
	Coefficients	**Std. Errors**
Covariates:		
Type of market		
=1 if boma market	-0.167	(0.806)
Market		
=1 if Chilumba	-0.481	(0.792)
=1 if Chitakale	-0.0619	(0.791)
=1 if Chitipa Boma	-0.325	(0.824)
=1 if Dedza Boma	-0.232	(0.793)
=1 if Ekwendeni	-0.256	(0.773)
=1 if Jali	-0.702	(0.810)
=1 if Karonga Boma	0.0836	(0.805)
=1 if Kasungu Boma	4.370***	(0.795)
=1 if Liwonde	-0.163	(0.783)
=1 if Lunzu	0.166	(0.801)
=1 if Mangochi Boma	-0.355	(0.817)
=1 if Mbulumbuzi	0.0649	(0.801)
=1 if Mchinji Boma	1.224	(0.800)
=1 if Mitundu	-0.276	(0.822)
=1 if Mponera	-0.132	(0.812)
=1 if Mwanza Boma	0.219	(0.793)
=1 if Mzimba Boma	0.490	(0.789)
=1 if Nchalo	-0.0381	(0.768)
=1 if Nkhatabay Boma	-0.170	(0.796)
=1 if Nkhotakota Boma	0.540	(0.807)
=1 if Nsalu	-0.570	(0.822)
=1 if Nsanje Boma	0.569	(0.827)
=1 if Ntcheu Boma	-0.919	(0.809)
=1 if Phalombe Boma	-0.171	(0.820)
=1 if Rumphi Boma	-0.298	(0.805)
=1 if Salima Boma	1.377	(0.841)
=1 if Thyolo Boma	-0.177	(0.794)
Month		
=1 if February	-0.487	(0.498)
=1 if March	-0.351	(0.505)
=1 if April	-0.328	(0.508)
=1 if May	0.522	(0.503)
=1 if June	-0.396	(0.508)
=1 if July	-0.821	(0.499)
=1 if August	-0.558	(0.505)
=1 if September	-0.786	(0.514)
=1 if October	-0.440	(0.514)
=1 if November	-0.633	(0.512)
=1 if December	-0.277	(0.512)
Year		
=1 if 2008	0.0816	(0.553)

	=1 if 2009	0.243	(0.553)
	=1 if 2010	0.455	(0.555)
	=1 if 2011	0.777	(0.554)
	=1 if 2012	0.738	(0.550)
	=1 if 2013	1.650**	(0.545)
	=1 if 2014	1.104*	(0.541)
	=1 if 2015	0.981	(0.544)
	=1 if 2016	0.275	(0.561)
	=1 if 2017	0.631	(0.586)
Constant		2.903***	(0.786)

Note: N= 2914; ***, **, * indicates that the corresponding coefficient estimates are statistically significant at the 1%, 5%, and 10% level respectively.