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The impact of food price shocks on weight loss: Evidence from the adult population of Tanzania

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Abstract

Undernourishment is still widespread in Tanzania, while obesity is becoming an issue of magnitude similar to undernutrition in the country. In this paper we examined the impact of an increase in maize prices on the nutritional status of Tanzania's adult population. We found that undernutrition increases as a result of increased prices, while the overweight and obese decrease their energy intake. The study presents evidences of the so called early stage of the nutritional transition that characterize developing countries. All in all, these findings are suggestive of the fact that food price shocks should be taken into consideration when designing policy and programmes aiming at addressing malnutrition in low income countries.

Keywords: Food price shocks, food demand models, malnutrition, Tanzania

JEL Classification : **C31; D12; D13; I31 ; Q18**

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1 Introduction

In the last decade, food price crises have been a major issue in sub-Saharan African (SSA) countries, with substantial negative effects on the welfare of the most vulnerable segments of the population given their predominantly food net buyer position. Tanzania is not an exception and its cereal prices are marked by large variability mainly due to weather shocks and seasonality (Baffes et al., 2015) but also because of discretionary policy interventions on markets. Maize represents the main source of calorie intake amongst poor and vulnerable households and it is the main target crop of these policy measures laid down ––in principle— to ensure food security and price stability (FAO-MAFAP, 2013). While high agricultural prices benefit net sellers, cereal price levels are critical for nutrition because they can crowd out household consumption and off-set expenditures devoted to other more nutritious foods such as animal-source foods, legumes and vegetables (Block et al., 2004; Torlesse et al., 2003; de Brauw, 2011).

The welfare consequences of changes in food prices remain a matter of serious concern for both researchers and policymakers and understanding their implications is a key element for guaranteeing food security. The usual approach followed in the empirical literature to evaluate the impact of higher food prices on households' welfare focuses on simulating the effects of price changes on several measures of the monetary value of food consumption or total expenditure (Anríquez et al., 2013). More recently, several studies provide support to the idea that the assessment of the impacts of increased food prices on households´ welfare should move beyond such money-metric measures. Indeed, price or income shocks ultimately affect the nutritional status of the population, changing households' dietary intake patterns (Ecker and Qaim, 2011). At this purpose, there is a growing body of literature focusing on assessing the impact of price, income and policy shocks on food security and nutrition indicators, concentrating mainly on measures based on calorie and nutrients availability. For example, changes in the prevalence of undernourishment and micronutrient deficiencies due to shocks at the national level have been predicted (see Ecker and Qaim, 2011; Anríquez et al., 2013). Nevertheless, a broader focus that includes the impacts of shocks on anthropometric measures is still missing and could be useful in order to better understand the determinants of malnutrition in the adult population. In this respect, anthropometric indicators such as the Body Mass Index (BMI) are commonly used to measure the nutritional status of a population since they are directly capturing individual level characteristics, eliminating the effect of other factors such as food losses, intra-household food distribution, individual health and activity levels (de Haen et al., 2011). While the use of anthropometric measures for young children is considered one of the main indicators to monitor change in the nutritional and health status in developing countries (de Haen et al., 2011), broadening the focus to cover the adult population can give critical insights for the formulation of policies aiming at improving Food Security and Nutrition (FSN) over populations affected by malnutrition.

In this paper, we seek bridging this gap by examining the potential impact of price shocks on individual-level nutritional outcomes. Specifically, we simulate the impact of a maize price shock on the BMI of Tanzania's adult population. While undernourishment continues to be a major concern in SSA countries (FAO et al., 2015), the number of countries facing increased prevalence of overweight and obesity in the adult population has been raising (Popkin et al., 2012; Hoffman, 2001). Further, in many poor countries, undernourishment and obesity are usually coupled with micronutrient deficiencies as the result of poor and inadequate diets (Keding et al. 2013; Damms-Machado et al., 2012). The coexistence of hunger, excess of calorie intake and micronutrient deficiency is defined as the 'triple burden' of malnutrition (Gómez et al., 2013; Keding et al. 2013; Pinstrup-Andersen 2007; Labadarios, 2005). Consequences of the three dimensions of malnutrition are multiple and widespread including poor health outcomes, lower levels of cognitive skills and lower income levels, higher unemployment rates, greater public health costs and loss of GDP growth (Horton et al., 1993; Haddad et al., 2003; Alderman et al., 2006 amongst others).

Tanzania is an appropriate example where the consequences of food price changes on malnutrition can be analyzed. Nearly 30 percent of Tanzania's population lived in 2012 under the national poverty line (World Bank, 2015). At national level, the energy supply does not meet the population's average energy requirements and micronutrient deficiencies are widespread (URT, 2013). While undernourishment continues to be one of the major concerns in the country, overweight and obesity have increased in recent years (URT, 2013). For example, the prevalence of obesity amongst women age 15-49 was equal to 18 percent in 2004 while it increased to 22 percent in 2010 (TDHS, 2010).

For our analysis, we made use of the Tanzania National Panel Survey (TZNPS) collected between 2010 and 2011 by the Tanzanian National Bureau of Statistics (TNBS) in collaboration with the Living Standard Measurement Study (LSMS) project of the World Bank. We first estimate price and expenditure elasticities using a quadratic almost ideal demand system (QUAIDS) in order to evaluate the extent to which changes in prices affected household food, and therefore calorie demand patterns. Second, we simulate the impact of a 20 percent maize price increase on the total calorie intake of the households and then we distribute it across the household's members to evaluate the effect on their nutritional status. Since the TZNPS collected data on consumption at household-level while anthropometrics are registered at individual-level, we are forced to make some assumptions on the intra-household distribution of calorie changes. We address this issue relying on the standard hypothesis that food is distributed within the household in direct proportion to expected members' shares of the household's total adult male consumption equivalent (Fiedler et al. 2012). Finally, we move from individual calorie to weight changes using both a static and a dynamic calorie-to-weight model. The second model was recently developed by Hall et al. (2011) and applied by Lin et al. (2011) to analyze the impact of taxation on sugar beverages on weight loss in the US. This last step allows us to: (i) calculate the impact of the price shock on our indicators of nutritional outcomes; and (ii) predict its effect on underweight, overweight and obesity prevalence at the national level in the short and medium term.

Overall, we find an increase of undernutrition and a decrease in over nutrition as a result of an increase in the price of maize, the main food staple in Tanzania. We conclude that this nutrition pattern is due to the limited substitution possibilities in a country such as Tanzania. Further, our results confirm the increasing prevalence of obesity in Tanzania already noted in previous studies and suggests that the country like other low- and middle-income countries is at an early stage of the nutritional transition. Finally, as the government of Tanzania appears to be sustainably interested in improving the nutritional status of its population, this study suggests the need to also anticipate interventions to cope with high food prices should these prices soar again in the future.

The remainder of the paper is organized as follows: Section 2 reviews the literature on food price shocks and impact on nutritional status of affected population. Sections 3 discusses the data as well as variables constructed to carry out the analysis. Section 4 describes the methods used. Section 5 presents descriptive statistics of variables used in the analysis. In section 6, the results of the analysis are discussed while conclusions and policy messages are drawn in section 7.

2 Literature review

Most of the empirical works on this topic use estimated price and expenditure elasticities to simulate the impact of price and income shocks on different measures of the household's welfare, i.e. living standards based on monetary values such as food and total consumption expenditure. This strand of the literature is quite extensive (for example Ivanic and Martin, 2008; De Janvry and Sadoulet, 2009; De Hoyos and Medvedev, 2011; Vu and Gleewe, 2011; Minot and Dewina, 2013) and it usually relies on the concept of compensating variation, the amount of money that has to be transfered to the household after a price change to make it as well-off as it was before. These studies are based on the methodologies proposed by Singh et al. (1986) and refined by Deaton (1989, 1997) which measures the welfare impacts imputing changes in relative food prices to the household's production and consumption of the corresponding food crops (De Janvry and Sadoulet, 2008). Among these, Tefera et al. (2012) and Magrini et al. (2016) derive the impacts of increased food prices focusing specifically on selected SSA countries —Ethiopia, Tanzania, Niger and Malawi— and specific sub-groups of the population. Brambila et al. (2009) use a series of different poverty indicators based on the simulated food expenditure variation such as the headcount ratio or the poverty gap to evaluate the welfare impacts of food price shocks in Zambia.

Several other papers have examined food, calorie and nutrient demand in SSA countries in order to assess potential outcomes of the different dimensions of malnutrition and their possible policy implications. Some authors have examined food, calorie and nutrient elasticities of demand to provide useful insights on how income and price changes affect household food and nutrient demand patterns. For example, Abdulai and Aubert (2004a) examine the responsiveness of household calorie demand to income in Tanzania, finding a positive and linear relationship. They also identify that lower food prices may improve household calorie intake. Abdulai and Aubert (2004b) analyze the relationship between food demand patterns, food prices and expenditures in Tanzania, extending the analysis to other nutrients related to undernutrition and obesity, apart from calories. Once again, they show the high response of food and macro- and micronutrient demand to changes in food prices and income. Higher maize prices will lead to lower household nutrient availability.

Ecker and Qaim (2011) estimate calorie and some relevant nutrient elasticities in Malawi in order to evaluate the potential impacts of income-related and staple price regulating policies and shocks. They focus on simulating the household prevalence of particular macro- and micronutrient deficiencies based on reference levels that account for household composition after several income and price changes. A maize price increase can lead to a decrease in the consumption of certain micronutrients. They find evidence to support that income-related policies are more appropriate to improve the population's nutritional status. Anríquez et al. (2013) simulate the impact of price shocks on nutritional outcomes in eight developing countries, among which we find Kenya and Malawi. More specifically, they evaluate undernourishment following a similar approach to calculate it to that of Ecker and Qaim. They find a decreasing calorie intake and negative distributional effects of calorie consumption within the country, hurting even more the food insecure. Finally, Harttgen et al. (2015) simulate the impact of income and price shocks on Malawi’s food security. In this case, they use calorie availability as a measure of food availability and some poverty measures —poverty headcount, poverty gap and severity index—, this time using the simulated calorie distribution after the shocks as a threshold to assess food poverty. They also find an increase in poverty and food insecurity in the face of a staple price shock.

The translation from calorie to weight changes has been assessed in several studies in the US (for example Finkelstein et al. 2010; Lin et al., 2011; Ruff and Zhen, 2015), the UK and Ireland (Briggs et al. 2013a,b) and South Africa (Manyema et al. 2014). To the best of our knowledge, the translation from calorie to weight changes is used to examine how trends in the prevalence of overweight respond to changes in food prices specifically resulting from the taxation of unhealthy foods such as soft drinks high in sugar (Lin et al., 2011).

3 The data

3.1 National Panel Survey for Tanzania

The data used in the analysis were sourced from the 2010/2011 TZNPS. The survey was conducted from October 2010 to September 2011. It is based on a stratified, multi-stage cluster sample design and has a nationally representative sample of 3,924 households.

We primarily used the survey's food consumption and anthropometry modules. In particular, the consumption module reports data on household food consumption and on food expenditures using a seven-day recall. It reports quantities consumed at the household level for 59 food items differentiating them according to their source (purchases, own-production and gifts and other sources) and expenditures for purchased foods. The data sourced from the consumption module provides all the necessary information to estimate the household response to maize price shocks. In a similar manner, the anthropometry module reports data on body weight, height, age and gender of every individual by household and, again, these data allow us to calculate the adult BMI, underweight and overweight prevalence at the country level.

3.2 Construction of household and individual level variables

Food items were aggregated into eight groups which include maize, other cereals, livestock and livestock products, fruits and vegetables, starches, pulses, oils and other foods. The selection of food groups was based on the usual aggregated basic food groups. Maize was disaggregated from the cereal group in order to simulate the shock on it. The "other foods" group comprise the following foods: bread, buns, cakes, macaroni, spices, sugar, sweets, nuts and seeds, tea, coffee and other beverages. While reporting more disaggregated elasticities can provide new insights, we would still be left with only a partial picture of households' demand for maize. Aggregating food groups over a more disaggregated approach has the advantage that estimation becomes simpler because of the more reduced number of parameters (Abdulai and Aubert, 2004a; Ecker and Qaim, 2011; Magrini et al., 2016). Finally, data on food consumption were aggregated by adding up food quantities for each group considered in the analysis and by computing the weighted average of the single item prices, using the consumption shares as weights.

To calculate household calorie consumption from the reported food quantities, we applied conversion factors of the Tanzania food composition tables (Tanzania Food Composition Tables, 2008). For each household and each food item, we matched the survey data on consumed food with their associated calorie intake.

The prevalence of adult underweight, overweight and obesity were computed following the WHO recommended cutoffs (WHO, 2006). The prevalence of underweight was defined as the percentage of population with BMI under 18.5 (BMI ≤ 18.5), the prevalence of overweight as the percentage of population with BMI between 25 and 29.9 (25 ≤ BMI < 30) and the prevalence of obesity as the percentage of population with BMI over 30 (BMI ≥ 30).

After excluding respondents aged under eighteen and over 65 and respondents with implausible energy consumptions, the sample consists of 3,652 households and 8,991 respondents (5,965 correspond to rural respondents while 3,026 to urban respondents; 4,722 to net buyer households split into 2,286 to rural net buyer households and 2,436 to urban net buyer households.

Households with energy intakes per capita below 500 and above 5000 kilocalories were considered outliers due to biologically implausible energy intake values (Ecker and Qaim, 2011).

4 Methods

4.1 Quadratic almost ideal demand models

The impact of a price shock on demand is a result of two components —the substitution effect and the income effect. The substitution effect is the change in the consumption of a commodity due to a change in its price for a constant level of utility. The income effect is the change in consumption due to the increase (or decrease) in purchasing power while relative prices remain constant. To model the demand of the eight food group items specified above we use the QUAIDS model (Banks et al., 1997). This model allows to estimate price and income demand elasticities, taking into account substitution between food groups in response to changes in prices or incomes. The QUAIDS model is a generalization of the Deaton and Muellbauer almost ideal demand system (AIDS) to include a quadratic expenditure term. Although there are several alternative models such as the Linear Expenditure System (Stone, 1954), the Rotterdam Model (Theil, 1965; Barten, 1964) or the Indirect Translog System (Christensen et al., 1975), the AIDS model appears to be more appropriate due to its analytical simplicity and consistency with theory (Magrini et al., 2016).

The introduction of the quadratic expenditure term in the QUAIDS model permits to appropriately model consumer behavior, as it allows goods to be nonlinearly related to expenditure and thus to be luxuries at certain income levels and necessities at other income levels (Banks et al., 1997). This strand of literature considers that household preferences can be defined in the QUAIDS model by the following indirect utility function ($lnV(p,m)$), which is derived from the generalization of the Price-Independent Generalized Logarithmic (PIGLOG) demand system — demand system with budget shares linear in log total expenditure:

$$lnV(p,m) = \left[\left\{ \frac{lnm - lna(p)}{b(p)} \right\}^{-1} + \lambda(p) \right]^{-1} \quad [1]$$

where $(lnm - lna(p))/b(p)$ is the indirect utility function of a PIGLOG demand system, m is total household expenditure on food and $lna(p)$, $b(p)$ and $\lambda(p)$ are functions of a vector of prices (p). Specifically, $lna(p)$ is defined as the following translog function:

$$lna(p) = \alpha_0 + \sum_{i=1}^{k} \alpha_i \, lnp_i + \frac{1}{2} \sum_{i=1}^{k} \sum_{j=1}^{k} \gamma_{ij} \, lnp_i lnp_k \quad [2]$$

where k is the number of food groups in the system, subscripts i and j are food groups in the system and p_i and p_j are the prices of food group i and food group j respectively.

$b(p)$ is the Cobb-Douglas price aggregator function defined as:

$$b(p) = \prod_{i=1}^{k} p_i^{\beta_i} \quad [3]$$

and $\lambda(p)$ is defined as follows:

$$\lambda(p) = \sum_{i=1}^{k} \lambda_i \, lnp_i \quad [4]$$

where α_i, γ_{ij}, β_i and λ_i are parameters to be estimated. The QUAIDS model is subject to a number of constraints in its parameters derived from demand theory: adding up, homogeneity and Slutsky symmetry. The adding up condition implies that the system of expenditure share equations add up to total expenditure ($\sum w_i = 1$), and thus has to meet the following restrictions:

$$\sum_{i=1}^{k} \alpha_i = 1; \quad \sum_{i=1}^{k} \beta_i = 0; \quad \sum_{i=1}^{k} \lambda_i = 0; \quad \sum_{j=1}^{k} \gamma_{ij} = 0 \qquad [5\text{-}8]$$

Demands are homogenous of degree zero in all prices and income. This requires the compliance with the following restriction:

$$\sum_{j=1}^{k} \gamma_{ij} = 0 \qquad [9]$$

And finally, Slutsky symmetry requires that:

$$\gamma_{ij} = \gamma_{ji} \qquad [10]$$

The Roy's identity reformulates Shephard's lemma in order to get a Marshallian demand function for an individual and a good from a specific indirect utility function (Roy, 1947). Applying Roy's identity to Equation [1], the expenditure share equation for food group i is defined in the QUAIDS as:

$$w_i = \alpha_i + \sum_{j=1}^{k} \gamma_{ij} ln p_j + \beta_i ln\left\{\frac{m}{a(p)}\right\} + \frac{\lambda_i}{b(p)}\left[ln\left\{\frac{m}{a(p)}\right\}\right]^2, \qquad i = 1, \dots, k \qquad [11]$$

where w_i is the expenditure share for food group i, m is total household food expenditure and p_j is the price of food group j. Note that when λ_i is 0 for all i then the expenditure share equation would be that of the AIDS model.

A total of 4 demographic effects —household size, age of the household head, number of children in the household and the household head's level of education— are controlled for in the model to account for other additional factors apart from prices and total expenditure affecting household food demand. For example, increasing household size may affect food demand by increasing the consumption of cheaper sources of calories and decreasing the consumption of more expensive foods.

Following Ray (1983) and Poi (2012), the expenditure share equation for food group i including demographics modifies Equation [11] in the following way:

$$w_i = \alpha_i + \sum_{j=1}^{k} \gamma_{ij}\, lnp_j + (\beta_i + \eta_i' z) ln\left\{\frac{m}{\overline{m}_0(z)a(p)}\right\} + \frac{\lambda_i}{b(p)c(p,z)}\left[ln\left\{\frac{m}{\overline{m}_0(z)a(p)}\right\}\right]^2 \qquad [12]$$

where z is a vector of demographic variables and $\overline{m}_0(z)$ and $c(p,z)$ are defined by the following equations:

$$\overline{m}_0(z) = 1 + \rho' z; \qquad c(p,z) = \prod_{j=1}^{k} p_j^{\eta_j' z} \qquad [13\text{-}14]$$

One critical problem of using survey data to model demand systems is that surveys report zero expenditure shares for food items for those households in which the specific food item is not consumed. This causes censored dependent variables that lead to biased elasticity estimates. We use the two step procedure developed by Shonkwiler and Yen (1999) to correct for this. The procedure consists in first estimating a multivariate probit regression to calculate the probability of consuming each specific food aggregate. From the multivariate probit we estimate the standard normal cumulative distribution function and the standard normal probability density function. The latter permits to modify Equation [12] to account for zero expenditure shares as follows:

$$w_i^* = \Phi(\hat{\tau}_i' z) w_i + \delta_i \varphi(\hat{\tau}_i' z) + \xi_i \qquad [15]$$

where w_i^* is the observed expenditure share for food group i, $\Phi(.)$ and $\varphi(.)$ are the cumulative distribution function and the probability density function based on the multivariate probit regression, $\hat{\tau}_i'$ is the vector of associated parameters from the multivariate probit and δ_i is the covariance between the error terms in the QUAIDS model and the multivariate probit. Finally, the uncompensated price elasticity of good i with respect to changes in the price of good j and the expenditure elasticity can be defined, respectively, as follows:

$$\begin{aligned} \in_{ij} = \frac{\partial w_i^*}{\partial lnp_j} = \frac{1}{w_i}\Bigg(\gamma_{ij} - \left[\beta_i + \eta_i' z + \frac{2\lambda_i}{b(p)c(p,z)} ln\left\{\frac{m}{\overline{m}_0(z)a(p)}\right\}\right] \\ \times \left(\alpha_j + \sum_l \gamma_{jl} lnp_l\right) \\ - \frac{(\beta_j + \eta_j')\lambda_i}{b(p)c(p,c)}\left[ln\left\{\frac{m}{\overline{m}_0(z)a(p)}\right\}\right]^2\Bigg) \Phi(\hat{\tau}_i' z) + \varphi_i \tau_{ij}\left(1 - \frac{\delta_i}{w_i}\right) \\ - \delta_{ij} \end{aligned} \qquad [16]$$

$$\mu_i = \frac{\partial w_i^*}{\partial lnm} = 1 + \frac{1}{w_i}\left[\beta_i + \eta_i' z + \frac{2\lambda_i}{b(p)c(p,z)} ln\left\{\frac{m}{\overline{m}_0(z)\alpha(p)}\right\}\right] \Phi(\hat{\tau}_i' z) \qquad [17]$$

The compensated price elasticity of good i with respect to changes in the price of good $j$can be defined from the Slutsky equation as:

$$\epsilon_{ij}^c = \epsilon_{ij} + \mu_i \omega_j \qquad [18]$$

Since food prices are not usually included in households' expenditure surveys they are typically approximated by their unit values. The unit values are computed as the ratio of the expenditure on the purchased food item to the purchased quantity. However, some authors consider that using unit values as proxies of prices can lead to inconsistent estimates of price elasticities of demand because they do not account for quality effects and measurement errors (Deaton, 1988; Alfonzo and Peterson, 2006). Following the approach used by Alfonzo and Peterson (2006) and Ecker and Qaim (2011), price indices are approximated using predictions of unit values which specifically account for geographical location and seasonal changes in prices. Unit values were calculated item-specifically and used to impute prices to non-purchased consumed quantities accounting for location and time, for which the survey does not report expenditures. Unit values were then corrected to account for food item expenditures, household characteristics and geographical and seasonal variations in prices. Geographical and seasonal characteristics in prices are taken into account by determining clusters of households defined by region, whether the household belongs to rural or urban areas and the month in which the survey was conducted. In this way, prices are corrected for quality by considering only the part of the unit value which is constant within the same location and time (Alfonzo and Peterson, 2006). Thus prices were approximated by the following two equations:

$$lnu_i = \alpha_i + \beta_i x_i + \sum_{k=1}^{K} \gamma_{ik} z_k + \sum_{c=1}^{C-1} \rho_{ic} D_c + \sum_{ae=1}^{AE} \epsilon_{iae} D_{ae} + \sum_{m=1}^{M} \mu_{im} D_m + \varepsilon_i \qquad [19]$$

where u_i is the item-specific unit value, x is food expenditure, z_{ik} is a vector of household characteristics and D_c are the cluster dummies, D_{ae} dummies for each agroecological zone and D_m monthly dummies.

$$ln\hat{\pi}_i = \hat{\alpha}_i + \sum_{c=1}^{C-1} \hat{\rho}_{ic} D_c \qquad [20]$$

where $ln\hat{\pi}_i$ is the price approximation and $\hat{\alpha}_i$ and $\hat{\rho}_{ic}$ are the estimates of α_i and ρ_{ic} from Equation [19].

Once we estimate the elasticities using the QUAIDS model we use them to derive the changes in calories (ΔE) consumed by each household from the uncompensated own- and cross-price elasticities specified in Equation [16], i.e.

$$\Delta E = \frac{\Delta p_j}{p_j} \sum_{i=1}^{k} \in_{ij} e_i q_i \qquad [21]$$

where $\in_{ij}$ is the uncompensated elasticity of food group i with respect to the change in the price of food group j ($\Delta p_j / p_j$) , q_i is the quantity consumed of food item i and e_i is the technical coefficient measuring the caloric content of food item i contained in each unit of q_i. From equation [21] we obtain an aggregate measure of the total change in calories experienced by the households. Since the ultimate objective of the present exercise is to look at the impact of the price shock on the anthropometric indicators at individual level, we still need two further steps. First, we need to distribute the aggregate calorie consumption variation (ΔE) across household's members to see how it affects the individual level of calorie intake. Second, we need to convert the variation of the calorie intake into a change of the body weight so that we can compare the anthropometric indicators before and after the price shock.

4.2 Intra-household distribution of changes in calorie consumption

The LSMS–ISA project collected food consumption data at household level and individual-level anthropometric data of the household members. However, no individual level on food consumption was collected thus raising concerns on how to deal with intra-household allocation of food. Using per capita measures to estimate the allocation of food and thus calories is likely to lead to biased estimates of calorie loss. Supporting this hypothesis, Hyder et al. (2005) show that in some countries like Tanzania inequities favor men. In fact, intra-household allocation of food amongst family members might be unequal and ultimately determine different patterns of individual food and nutrient intake with respect to the recommended one (Carletto et al. 2013).

Keeping this caveat in mind, we relied on the standard hypothesis that food is distributed within the household in direct proportion to expected members' shares of the household's total adult male consumption equivalent (Fiedler et al. 2012). In other words, we assume that calories are distributed within the household according to the recommended calorie needs of each member. To compute the relative calorie requirements of each household member, we use the recommended daily calorie intakes from the UNU/WHO/FAO expert consultation (FAO, WHO and UNU, 2004). Further, we assumed a "moderate" Physical Activity Level (PAL) to calculate minimum calorie requirements. While assuming a "moderate" level of PAL might underestimate energy requirement of population subsets engaged with agriculture activities (D'Souza and Tandon, 2015), assuming a higher PAL could conversely overestimate calorie requirements for sedentary individuals. Thus, we set the required PAL equal to moderate.

Table 1 provides an example on how change in calorie intake was distributed for a household composed of two adults and two children including age, gender and physical activity of family members.

Table 1. Intra-household calorie allocation for a standard household

	Age (years)	Gender	Physical activity	Weight (kg)	Recommended Energy requirement (kcal/day)	Recommeded share of HH energy allocation (%)	Total HH Energy Changes (kcal/day)	Intra-household calorie change allocation (kcal/day)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Man	34	Male	Moderate	72	3,163.00	37%	-500.00	-185.00
Woman	30	Female	Moderate	58.4	2,427.60	28%	-500.00	-140.00
Child	5	Male	Moderate	-	639	7%	-500.00	-35.00
Child	13	Female	Moderate	-	2,375	28%	-500.00	-140.00
Total					8,604.60	100%		-500.00

Note: Author's analysis of 2010/2011 TZNPS

After computing each household member's recommended energy requirement, the change in total household calories resulting from equation [21] is allocated proportionally to each household member according to his/her share. The share is calculated by first computing the individual level required calorie intake based on gender, age and PAL, summing it up and then dividing individual energy requirement by the total (column (6)). Then, the estimated household calorie loss (column (7)) due to increased price of maize is distributed within the household based on shares presented in column (6). For example, due to an upward maize price shock, an adult woman in the family would experience a decrease in consumption of calories equal to 140 kcal on a daily basis.

4.3 Calorie to weight models

Once we determine the intra-household distribution of the calorie changes, we need to convert it in a weight-equivalent measure to be used for simulating the counterfactual BMI after the price shock. Changes in body weight are the result of an imbalance between energy intake and total energy expenditure (Chow and Hall, 2008). On the contrary, when energy intake and energy expenditure are balanced over a period of time, the individual reaches a steady state (FAO, WHO and UNU, 2004). Usually, to test how a change in energy calorie intake would affect body weight, a static model is used. The static model states that a cumulative energy deficit of 3,500 kilocalories is needed per pound of body weight loss (Chow and Hall, 2008) based on the assumption that each unit of body weight change corresponds to a fixed 75 percent of fat tissue and 25 percent of lean tissue change. Thus, the relation between changes in calorie intake and body weight is assumed to be a constant process such that it predicts a linear change in body weight over time (Lin et al., 2011).

However, weight change is actually a dynamic process that diminishes over time (Lin et al., 2011; Ruff and Zhen, 2015) and so the static model can overestimate weight loss or gain significantly (Katan and Ludwig, 2010; Lin et al., 2011; Ruff and Zhen, 2015). These authors give several reasons for this. First, the actual energy requirements of the individual depend on several factors —i.e. age, gender, weight, activity level and body composition— and energy requirements decrease (increase) with decreasing (increasing) weight. Thus, weight loss (or gain) slows down asymptotically under a constant change in calorie intake over time until a new steady state is again achieved. Second, the fixed percentage of fat and lean tissue lost per unit of body weight assumed by the static model actually does not hold. As a consequence, changes in total weight depend nonlinearly on body fat mass, so the relation between energy and weight change varies over time. In addition, energy intake and energy expenditure are also affected by this dynamic change in body fat and lean tissue, due to the fact that the energy expenditure rate of lean tissues is larger than that of fat tissues.

For all these reasons, in the paper we use both the static model and the recently developed dynamic model (see Appendix for more details) proposed by Hall et al. (2011) and applied by Lin et al. (2011) to analyze the impact of taxation on sugar beverages on weight loss in the US.

5 Descriptive statistics

Table 2 presents the budget shares for the different food groups considered in the analysis and the average daily calorie consumption per adult household member. The data are further disaggregated by rural and urban households as food consumption may respond differently to changes in food prices across households' categories.

Table 2. Budget shares referring to overall consumption and average overall calorie consumption in the baseline (2010/2011).

	Total	Rural	Urban	Net buyer	Rural net buyer	Urban net buyer
Budget Shares						
Maize	0.18	0.19	0.14	0.16	0.19	0.13
Other cereals	0.12	0.12	0.14	0.14	0.13	0.14
Livestock and Products	0.20	0.19	0.21	0.20	0.19	0.21
Fruits and Vegetables	0.14	0.13	0.14	0.13	0.13	0.14
Starches	0.09	0.11	0.07	0.08	0.09	0.06
Pulses	0.05	0.06	0.04	0.05	0.05	0.04
Oils	0.05	0.04	0.05	0.05	0.04	0.06
Other Foods	0.17	0.16	0.21	0.19	0.17	0.21
Average calorie intake (kcal / day) per adult household member						
Maize	701.1 (577.4)	737.5 (633.2)	629.4 (438.6)	679.0 (494.4)	733.8 (573.9)	627.5 (399.0)
Other cereals	345.4 (368.9)	310.9 (387.8)	413.5 (317.7)	404.4(345.7)	372.5 (383.4)	434.3 (303.0)
Livestock and Products	207.9 (246.3)	197.1 (242.1)	229.1 (253.0)	208.7 (244.0)	183.9 (224.7)	231.9 (258.7)
Fruits and Vegetables	64.5 (65.2)	58.0 (62.5)	77.1 (68.6)	70.9 (69.5)	62.2 (68.6)	79.1 (69.4)
Starches	310.7 (433.4)	364.3 (484.7)	204.9 (279.2)	240.2 (303.4)	302.2 (367.0)	181.9 (212.1)
Pulses	84.0 (87.6)	83.4 (94.7)	85.2 (71.6)	83.1 (81.0)	77.4 (89.4)	88.4 (71.8)
Oils	159.1 (125.5)	123.8 (129.9)	229.1 (175.6)	190.8 (165.5)	137.4 (131.3)	241.1 (178.2)
Other Foods	338.6 (316.0)	273.7 (289.8)	466.9 (326.1)	419.4 (328.7)	338.9 (313.3)	495.1 (324.9)
Total average calorie intake	2,211.4 (917)	2,148.6 (917)	2,335.4 (905)	2,296.5(904)	2,208.4 (895)	2,379.3 (905)

Note: Standard deviations in parenthesis. Source: Author's calculation based on 2010/2011 TZNPS

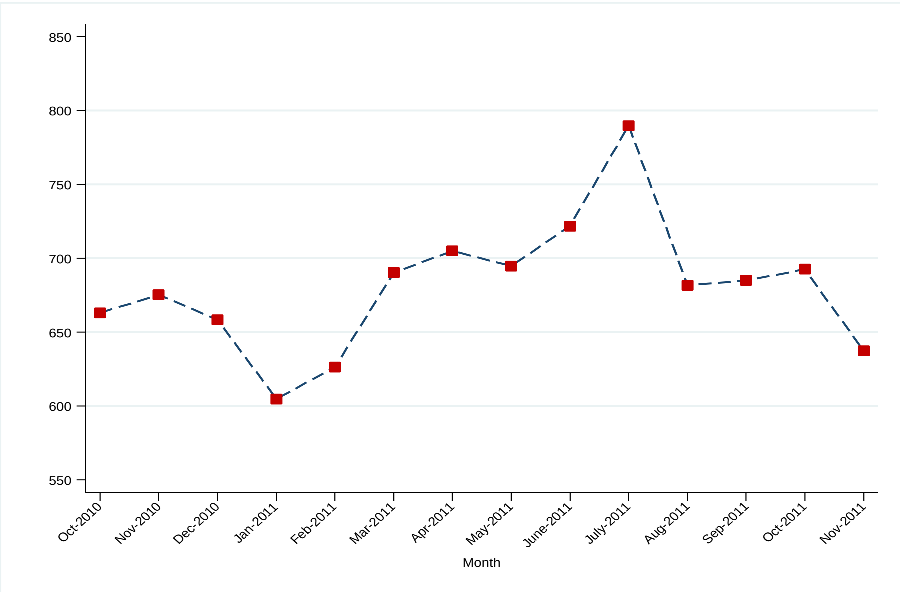
In addition, we examined (urban and rural) net buyers of maize since we believe they constitute two sub-segments of the population that could be highly affected by a shock in the price of maize. Average calorie consumption has been converted into daily adult household member to facilitate its comparison with reference levels from the literature.

Slightly more than 30 percent of the budget was devoted to cereals in both rural and rural net buyer households while urban and urban net buyer households allocated 28 and 27 percent of their budget respectively to the maize and the "other cereals" groups combined. Rural households and rural net buyer households allocated a higher proportion of their budget to maize (19% and 16% respectively), while urban and urban net buyer households allocated a larger or at least the same share to the "other cereals" group, showing that the share of consumed maize is larger in maize producing areas. There are no large differences in the budget devoted to livestock and its products, fruit and vegetables, pulses and oils between rural and urban households and rural and urban net buyer households.

The average calorie consumption reached 2,167 kilocalories per capita in 2011 (FAO-FAOSTAT, 2015), which suggests that our estimate of 2,211 for the total population is reasonable. On average, urban households consumed more calories than rural households (2,335 kilocalories per adult household member in urban households against 2,148 in rural areas). This pattern is repeated for net buyer households, although calorie consumption is higher in net buyer households both in rural and urban areas. Maize was the main source of calories for all households irrespective of their classification. This suggests high dependency on maize amongst Tanzanian population and thus high vulnerability to maize price shocks. The second source of calories in rural households was starches, whereas in rural net buyer households was the "other cereals" group. In contrast, in urban areas, the second source of calories was the "other foods" group followed by the "other cereals" group.

To set the percentage increase in the price of maize, we used information from the TZNPS. We calculated real retail prices based on what was reported in the household survey, as displayed in Figure 1 (below).

Figure 1. Evolution of real retail maize prices in Tanzania in the study period (Tanzanian Shilling/kg)



Note: Authors' calculation based on 2010/2011 TZNPS

We found that the retail maize price increased from 600 to 700 TZS between January and March 2011 and then remained above this level until the end of the year. In other words, the initial 17 percent shock in the real retail maize price has not been reabsorbed for at least 6 months and thus, in our exercise, we simulated an average increase of 20 percent to also account for price spike in July 2011. Our model does not account for price co-movements potentially arising from price shocks in international markets and leading to more complex substitution between food groups as well as real income effects. Moreover, given that the data set includes one observation per household during the period examined, we cannot account for the household specific price variation. As a result, the price variation Δp_j is considered fixed across households.

6 Results

6.1 Quadratic almost ideal demand models

The mean expenditure and uncompensated and compensated price elasticities of food demand for the rural and urban samples are given in Tables 3 and 4.

Table 3. Expenditure and price elasticities of food demand for rural households, means

	Maize	Other cereals	Livestock	Fruit and veg	Starches	Pulses	Oils	Other foods
	Expenditure elasticities							
	0.534	**1.554**	**1.414**	**0.737**	**0.653**	**0.602**	**0.636**	**1.345**
	(0.037)	(0.176)	(0.075)	(0.029)	(0.153)	(0.061)	(0.068)	(0.082)
	Marshallian (uncompensated) price elasticities							
Maize	**-1.064**	**0.188**	**0.090**	-0.015	**0.084**	**-0.068**	**0.043**	**0.209**
	(0.025)	(0.021)	(0.014)	(0.011)	(0.016)	(0.018)	(0.012)	(0.019)
Other cereals	0.052	**-1.235**	**-0.153**	-0.031	-0.012	**-0.067**	-0.005	**-0.102**
	(0.037)	(0.065)	(0.033)	(0.024)	(0.024)	(0.025)	(0.019)	(0.039)
Livestock	**-0.086**	**-0.096**	**-0.943**	**-0.028**	**-0.076**	**-0.038**	**-0.031**	**-0.116**
	(0.019)	(0.021)	(0.018)	(0.011)	(0.013)	(0.011)	(0.007)	(0.020)
Fruits and vegetables	-0.014	0.023	**0.072**	**-0.904**	0.015	**0.067**	-0.003	0.008
	(0.018)	(0.022)	(0.012)	(0.014)	(0.015)	(0.013)	(0.008)	(0.015)
Starches	**0.146**	**0.204**	0.009	0.013	**-1.145**	**-0.051**	**-0.099**	**0.270**
	(0.034)	(0.046)	(0.029)	(0.021)	(0.031)	(0.019)	(0.020)	(0.058)
Pulses	**-0.081**	**0.212**	0.021	**0.095**	**0.067**	**-1.036**	**0.057**	**0.063**
	(0.032)	(0.051)	(0.021)	(0.022)	(0.029)	(0.053)	(0.027)	(0.028)
Oils	**-0.104**	**-0.141**	0.026	0.035	**0.162**	0.049	**-0.813**	**0.150**
	(0.029)	(0.046)	(0.020)	(0.020)	(0.025)	(0.035)	(0.032)	(0.027)
Other foods	**0.117**	**-0.132**	**-0.149**	**-0.056**	0.017	**0.160**	-0.013	**-1.289**
	(0.022)	(0.024)	(0.017)	(0.013)	(0.017)	(0.024)	(0.017)	(0.045)
	Hicksian (compensated) price elasticities							
Maize	**-0.961**	**0.250**	**0.194**	**0.056**	**0.141**	**-0.038**	**0.066**	**0.292**
	(0.025)	(0.021)	(0.013)	(0.010)	(0.015)	(0.018)	(0.012)	(0.016)
Other cereals	**0.353**	**-1.053**	**0.150**	**0.174**	**0.153**	0.020	**0.061**	**0.142**
	(0.027)	(0.052)	(0.019)	(0.016)	(0.025)	(0.024)	(0.016)	(0.025)
Livestock	**0.188**	**0.070**	**-0.667**	**0.158**	**0.074**	**0.042**	**0.029**	**0.106**
	(0.014)	(0.017)	(0.015)	(0.008)	(0.012)	(0.009)	(0.005)	(0.014)
Fruits and vegetables	**0.129**	**0.110**	**0.216**	**-0.807**	**0.093**	**0.108**	**0.028**	**0.124**
	(0.017)	(0.021)	(0.012)	(0.014)	(0.014)	(0.013)	(0.008)	(0.014)
Starches	**0.273**	**0.280**	**0.137**	**0.099**	**-1.076**	-0.014	**-0.071**	**0.372**
	(0.026)	(0.035)	(0.019)	(0.015)	(0.031)	(0.020)	(0.021)	(0.041)
Pulses	0.036	**0.283**	**0.138**	**0.174**	**0.131**	**-1.002**	**0.082**	**0.158**
	(0.033)	(0.049)	(0.022)	(0.022)	(0.028)	(0.053)	(0.026)	(0.029)
Oils	0.020	-0.066	**0.150**	**0.118**	**0.229**	**0.085**	**-0.786**	**0.250**
	(0.028)	(0.044)	(0.018)	(0.018)	(0.025)	(0.034)	(0.032)	(0.027)
Other foods	**0.378**	0.026	**0.113**	**0.121**	**0.160**	**0.235**	**0.045**	**-1.078**
	(0.020)	(0.021)	(0.014)	(0.011)	(0.017)	(0.023)	(0.019)	(0.036)

Note: Standard errors in parenthesis. Source: Author's calculation based on 2010/2011 TZNPS

Table 4. Expenditure and price elasticities of food demand for urban households, means

	Maize	Other cereals	Livestock	Fandv	Starches	Pulses	Oils	Other foods
	Expenditure elasticities							
	0.303	**1.198**	**1.441**	**0.891**	**0.774**	**0.515**	**0.720**	**1.198**
	(0.073)	(0.209)	(0.075)	(0.034)	(0.247)	(0.093)	(0.069)	(0.043)
	Marshallian (uncompensated) price elasticities							
Maize	**-1.009**	**0.242**	**0.136**	-0.012	**0.134**	-0.030	-0.001	**0.237**
	(0.042)	(0.040)	(0.022)	(0.019)	(0.026)	(0.023)	(0.013)	(0.036)
Other cereals	**0.095**	**-1.142**	**-0.163**	0.028	-0.011	0.018	-0.006	-0.019
	(0.034)	(0.106)	(0.031)	(0.033)	(0.032)	(0.025)	(0.024)	(0.053)
Livestock	**-0.062**	**-0.161**	**-0.935**	**-0.034**	**-0.038**	**-0.035**	**-0.039**	**-0.136**
	(0.015)	(0.034)	(0.016)	(0.012)	(0.014)	(0.009)	(0.007)	(0.022)
Fruits and vegetables	**-0.076**	**0.062**	**0.057**	**-0.929**	-0.022	**0.031**	-0.006	-0.008
	(0.016)	(0.022)	(0.012)	(0.014)	(0.014)	(0.013)	(0.007)	(0.015)
Starches	**0.227**	0.103	0.016	-0.032	**-1.102**	-0.053	**-0.130**	**0.198**
	(0.047)	(0.111)	(0.041)	(0.039)	(0.055)	(0.032)	(0.035)	(0.099)
Pulses	-0.077	**0.271**	0.022	**0.110**	**0.079**	**-1.029**	0.049	0.060
	(0.044)	(0.073)	(0.030)	(0.032)	(0.041)	(0.077)	(0.036)	(0.042)
Oils	**-0.129**	-0.033	0.002	0.021	**0.085**	0.026	**-0.835**	**0.144**
	(0.029)	(0.051)	(0.018)	(0.019)	(0.025)	(0.033)	(0.030)	(0.029)
Other foods	0.034	-0.024	**-0.094**	**-0.043**	**-0.033**	**0.038**	**0.036**	**-1.111**
	(0.019)	(0.022)	(0.012)	(0.010)	(0.014)	(0.012)	(0.012)	(0.032)
	Hicksian (compensated) price elasticities							
Maize	**-0.967**	**0.284**	**0.200**	0.031	**0.154**	-0.017	0.015	**0.300**
	(0.042)	(0.035)	(0.021)	(0.016)	(0.026)	(0.022)	(0.013)	(0.030)
Other cereals	**0.259**	**-0.975**	**0.090**	**0.197**	0.069	**0.071**	**0.058**	**0.231**
	(0.034)	(0.081)	(0.031)	(0.018)	(0.040)	(0.024)	(0.017)	(0.028)
Livestock	**0.134**	0.040	**-0.632**	**0.169**	**0.057**	**0.029**	**0.038**	**0.165**
	(0.014)	(0.025)	(0.017)	(0.008)	(0.016)	(0.009)	(0.005)	(0.014)
Fruits and vegetables	**0.045**	**0.186**	**0.245**	**-0.804**	**0.037**	**0.071**	**0.042**	**0.178**
	(0.016)	(0.020)	(0.012)	(0.013)	(0.014)	(0.012)	(0.007)	(0.014)
Starches	**0.332**	**0.211**	**0.179**	**0.077**	**-1.051**	-0.019	**-0.088**	**0.359**
	(0.046)	(0.083)	(0.040)	(0.025)	(0.062)	(0.032)	(0.035)	(0.066)
Pulses	-0.007	**0.343**	**0.131**	**0.182**	**0.113**	**-1.006**	**0.076**	**0.168**
	(0.043)	(0.069)	(0.031)	(0.032)	(0.041)	(0.076)	(0.035)	(0.044)
Oils	-0.031	0.067	**0.154**	**0.122**	**0.132**	0.057	**-0.796**	**0.295**
	(0.028)	(0.046)	(0.019)	(0.017)	(0.026)	(0.033)	(0.030)	(0.028)
Other foods	**0.198**	**0.142**	**0.158**	**0.126**	**0.046**	**0.091**	**0.100**	**-0.861**
	(0.019)	(0.019)	(0.012)	(0.009)	(0.015)	(0.012)	(0.012)	(0.028)

Note: Standard errors in parenthesis. Source: Author's calculation based on 2010/2011 per adult household member).

The positive expenditure elasticities revealed that the consumption of all food groups increased with raising incomes. Maize had an expenditure elasticity below one, which indicates that it is a necessity good. This comes as no surprise as the population relies to a large extent on this staple to feed itself. Fruits and vegetables, pulses, oils and starches showed up as necessity goods too. On the other hand, livestock products, other cereals and the "other foods" group had expenditure elasticities above one, indicating that they are luxury goods. All this suggests that consumers tend to spend proportionally less on maize, fruits and vegetables, starches, pulses and oils and more on other cereals, animal-source products and the "other foods" group with raising incomes. These results appear to be in line with the consumption patterns typical of Tanzania: there is a high reliance on staples, especially on maize and cassava, while wheat and rice are considered more expensive sources of calories (Minot, 2010). Animal-source products are still not a large share of the diet, and fruits, pulses and vegetables are usually considered as less preferred foods (Keding et al., 2013).

All of the uncompensated and compensated own-price elasticities were statistically significant and negative, and thus consistent with demand theory. The relatively large uncompensated own-price elasticities revealed a high responsiveness of both rural and urban households to changes in food prices and indicated their vulnerability to food price shocks, especially a shock on maize prices. From now on we concentrate on the uncompensated own- and cross-price elasticities of maize because the focus of the study is an increase in its prices. Maize appeared to be more price elastic among rural households than among urban ones: urban households may respond less to changes in maize prices because it comprises a smaller share of their diet, despite being an important staple in urban settings too. We found substitution relationships between maize and the "other cereals" group, starches and the "other foods" group both in rural and urban settings. In other words, it looks like the demand for other energy-dense foods would increase following the maize prices rise. This suggests that calorie consumption is still the main concern of Tanzanian households, which tend to shift consumption towards similar high caloric content foods. Moreover, we found complementary relationships between maize and livestock products, fruits and vegetables, pulses and oils. This means that the demand for these foods would fall as maize prices rise. It is important to note that substitution possibilities could help reduce the impact of the maize price increase by softening the fall in energy intake caused by the shock and could even improve the protein and micronutrient intake. In this particular case, these substitution possibilities seem to be limited to other energy-dense foods with a low content in micronutrients, while the consumption of more nutritious foods would fall further.

6.2 Calorie consumption, weight and prevalence of underweight, overweight and obesity simulation results

A twenty percent maize price increase would result in an overall average reduction of calorie intake irrespective of the household classification, which is what Table 5 shows (for ease of interpretation, results have been converted to a daily basis). This result may be surprising as households that are net sellers of maize should observe a real income boost when maize prices increase. However, the net sellers included in our sample (1,229 as opposed to 4,722 net buyers) experience a slightly larger calorie loss on average than net buyers (-205 kcal for all net sellers, -208 kcal for rural net sellers and -170 kcal for urban net sellers) because their average calorie consumption of maize in the baseline is larger than in net buyer households. This could be related to the fact that the potential income boost is overlooked by not capturing the supply side effects of the price increase in the analysis, should the income boost be sufficient to compensate the overall increase in food prices driven by the increase in maize price. In this way, we could be overestimating to some extent the calorie loss as a result of the shock.

Table 5. Effects of a 20 percent maize price shock on calorie consumption (changes in calorie intake (kcal/day) per adult household member)

	Maize		Foods other than maize		All foods	
	Mean	Median	Mean	Median	Mean	Median
Total	-145.4	-121.7	6.6	4.9	-138.8	-117.6
Rural	-155.0	-133.3	7.9	5.4	-147.2	-126.0
Urban	-126.4	-108.3	4.1	4.1	-122.3	-105.4
Net buyer	-140.1	-115.5	5.7	5.0	-134.4	-110.8
Rural net buyer	-154.9	-126.1	7.6	6.4	-147.3	-118.8
Urban net buyer	-126.1	-109.9	3.9	4.1	-122.3	-106.3

Note: Author's calculation based on 2010/2011 TZNP.

From the perspective of calorie intake, substitution possibilities would not be enough to compensate for the drop in energy consumption. It appears that the total cross-price effects that result from the substitution and complementary relationships of maize would be relatively small compared to its own-price effects and would offset each other. Even if the price of maize increased by 20 percent, households would decrease their consumption of more expensive and nutritious foods in order to be able to purchase more of the staple or other cheap sources of calories.

The fall in calorie intake would be larger in rural settings. This can be associated with the difference in either the dietary patterns or the consumption response to the price shock across urban and rural areas. The mean own-price elasticity of demand is quite similar, yet somewhat higher in absolute value in rural areas. The share of maize in the diet is larger in rural areas, most likely because it is where it is produced. Imported cereals that compete with domestically produced maize are more available in urban areas. Surprisingly, the total cross-price effects that result from the substitution and complementary relationships of maize are slightly larger in rural areas, probably due to the larger share of the substitute starches in rural diets and of the complementary animal-source foods, fruits and vegetables and oils in urban ones. The fall of calorie intake of men would be larger relative to women but this is the result of the way the change in calories has been allocated across households, as men have higher energy requirements than women.

The overall average reduction in calorie intake resulted in the subsequent loss of average weight per adult household member when considering both the static and the dynamic models, as shown in Table 6.

Table 6. Weight changes predicted by the static and dynamic models over a 3, 6, 9 and 12 months period (kg/adult household member).

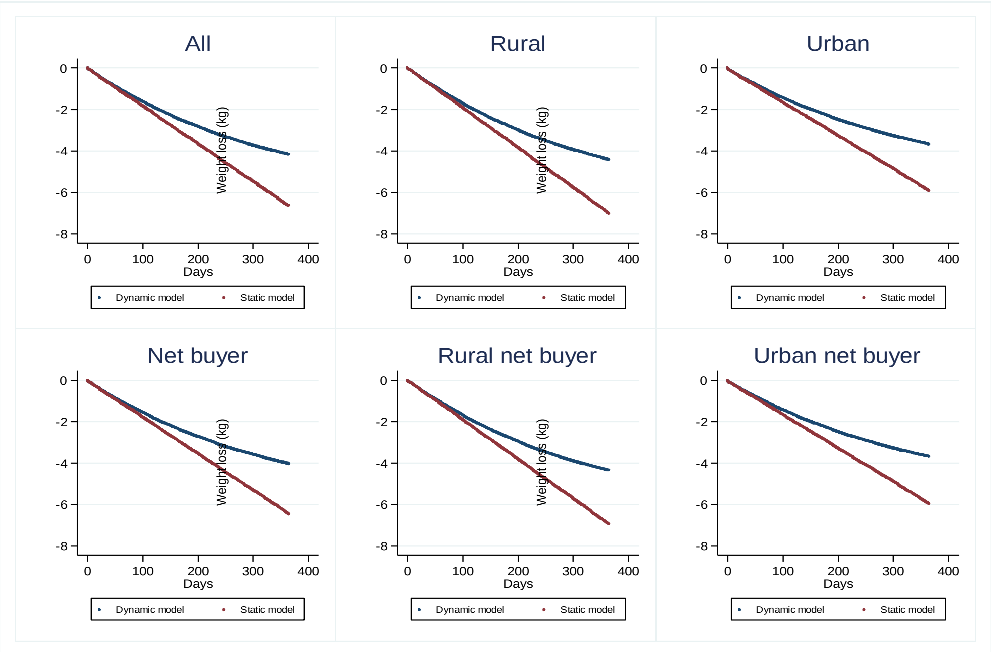
	Static model	Dynamic model
Total		
Baseline	58.7	58.7
3 months	-1.7	-1.5
6 months	-3.3	-2.6
9 months	-4.9	-3.5
12 months	-6.6	-4.2
Rural		
Baseline	57.3	57.3
3 months	-1.7	-1.6
6 months	-3.5	-2.8
9 months	-5.2	-3.7
12 months	-7.0	-4.4
Urban		
Baseline	61.6	61.6
3 months	-1.5	-1.3
6 months	-2.9	-2.3
9 months	-4.4	-3.1
12 months	-5.9	-3.7
Net buyer		
Baseline	60.3	60.3
3 months	-1.6	-1.4
6 months	-3.2	-2.5
9 months	-4.8	-3.4
12 months	-6.4	-4.0
Rural net buyer		

Baseline	58.3	58.3
3 months	-1.7	-1.5
6 months	-3.4	-2.7
9 months	-5.1	-3.6
12 months	-6.9	-4.4
Urban net buyer		
Baseline	62.3	62.3
3 months	-1.5	-1.3
6 months	-3.0	-2.3
9 months	-4.4	-3.1
12 months	-5.9	-3.7

Note: Baseline reports the average weight.

However, the results predicted by the dynamic model are much smaller and the difference between the results predicted by each of the models becomes larger over time. The static model generates a constant rate of decrease in weight over time, whereas the weight change predicted by the dynamic model tends to diminish over time, as can be seen clearly in Figure 2.

Figure 2: Evolution of average weight change over one year (kg/adult household member).



Note: Authors' calculation based on 2010/2011 TZNPS

If the study period were longer, the weight loss predicted by the dynamic model would level off at a certain stage in which the individual steady state would be once again attained. The results show that the static model overestimates the results of the dynamic model, making the results of the dynamic model more realistic. As expected from the results shown above on calorie consumption, average weight loss was higher in rural settings and higher for men than women.

As we showed that the results of the static model overestimate those of the dynamic one, in Table 7 we only reported the underweight, overweight and obesity prevalence predicted by the dynamic model.

Table 7. Percentage of underweight, overweight and obesity prevalence of adults predicted by the dynamic model

	Male			Female		
	Underweight	Overweight	Obese	Underweight	Overweight	Obese
Total						
Baseline	10.1	10.6	3.1	8. 4	18.7	9.9
3 months	19.2	9.3	2.8	13.0	16.7	9.1
6 months	25.9	8.1	2.6	17.5	15.0	8.7
Rural						
Baseline	10.2	7.6	2.0	9.3	16.3	6.7
3 months	19.8	6.6	1.8	14.4	14.3	6.1
6 months	27.4	5.6	1.7	19.8	12.7	5.8
Urban						
Baseline	10.0	17.3	5.7	6.5	23.7	16.4
3 months	17.9	15.5	5.1	10.3	21.6	15.1
6 months	22.5	13.7	4.7	12.7	19.7	14.5
Net buyer						
Baseline	10.2	13.5	4.3	8.6	21.1	14.3
3 months	18.9	12.2	3.8	13.1	19.3	13.3
6 months	24.5	10.5	3.5	17.0	17.8	12.7
Rural net buyer						
Baseline	10.8	8.7	2.8	10.5	18.2	9.7
3 months	20.5	7.9	2.5	15.7	16.0	9.1
6 months	27.0	6.8	2.3	21.1	15.0	8.7
Urban net buyer						
Baseline	9.5	18.6	6.0	6.8	23.9	18.7
3 months	17.2	16.7	5.2	10.5	22.4	17.4
6 months	21.9	14.5	4.7	13.0	20.4	16.6

Note: Author's calculation based on 2010/2011 TZNPS

The results are reported by gender because women are usually more vulnerable to nutrition outcomes (Keding et al. 2012) and because in developing countries they commonly tend to have higher rates of overweight and obesity. The table shows a steady increase in the short to medium term in the underweight rate and a fall in the overweight and obesity rates. This result was expected due to the reduction in calorie intake and the subsequent fall in weight of the population after the price shock seen above. We have to keep in mind that by not capturing the supply side effects of the price increase in the analysis, we could be overestimating to some extent the fall in average calorie loss and therefore we could be overestimating too the increase in the underweight and rate and the fall in the overweight and obesity rates. But what is striking about the results in

Table 7 is that the maize price increase had a relatively much larger effect in the underweight rate than in the overweight and obesity rates. Moreover, it had a larger effect in the overweight and obesity rates in rural settings than in urban ones.

These results are likely associated either with the dietary patterns of the overweight and obese individuals being less dependent on maize or with differences in the response of the demand of food to the price shock across the overweight and obese population. We classified households into three categories in order to reveal potential differences in baseline consumption patterns and in the change in calorie intake caused by the price increase among the overweight and obese population: (a) households with at least one underweight individual; (b) households with at least one overweight and/or obese individual; and (c) households with no underweight, overweight and/or obese individuals. Upon closer examination of the different dietary patterns across households, we see that households with at least one overweight or obese individual indeed consumed a smaller share of maize both in terms of budget and calorie shares. Households with at least one overweight or obese individual located in urban settings consumed a smaller share of maize than those located in rural areas. Apart from maize, households with at least one overweight and/or obese individual consumed less fruits and vegetables, starches and pulses and consumed more livestock products, oils and other foods —some of the obesogenic food items included in this group are common among overweight and obese women's diets in Tanzania (Keding et al., 2013).

These dietary patterns identified for households with at least one overweight and obese individual are consistent with previous studies in Tanzania (Keding et al., 2013) suggesting an early stage of the nutritional transition characterized by higher rates of overweight and obesity relative to those of underweight (Popkin et al., 2012; Keding et al., 2013). As seen above, the complementary and substitution relationships of maize would only favor the consumption of other energy-dense foods with a low content in micronutrients. In the face of the maize price increase two things might happen. On the one hand, the prevalence of underweight would rise contributing to undernutrition both in terms of calorie and micronutrient intake. On the other hand, the prevalence of overweight and obesity would also evolve but to a lesser extent. The overweight and obese individuals would be less vulnerable to the maize price increase in terms of calorie intake. Actually the impact could be considered positive from a nutrition standpoint although the maize price shock would worsen their micronutrient intake further negatively affecting their nutritional status.

The risk of food price increases on the burden of malnutrition at this early stage of the nutritional transition arises from the fact that dietary patterns generally shift towards energy-dense foods with low micronutrient contents. Even though this transition has not been yet achieved in Tanzania —Table 7 shows that while underweight becomes more prevalent, overweight and obesity become less prevalent— the evolution appears well under way. Moreover, this study shows that a 20 percent price increase of maize could contribute to both an increase of undernutrition (price increase effect for net buyers) and overnutrition (substitution effect to energy-dense foods) as the nutrition transition continues to develop. This calls for better targeted programs that address at the same time all aspects of malnutrition, broadening their target to include more nutritious foods and promoting the availability of certain food products that can improve the diversity of the diet. In this way, the nutritional status of the population could improve.

A few limitations of this work are acknowledged. It is recognized that these results depend on a few assumptions including (i) an appropriate demand model associated with the fact that prices in 2011-12 were already high compared to the long term trend; (ii) a correct intra-household calorie distribution; (iii) an accurate calorie-to-weight model; (iv) the exclusion of children from the analysis, and (v) the fact that by not capturing the supply side effects of the price increase we overlook a potential income boost in net seller households, possibly overestimating to some extent the increase in the underweight rate and the fall in the overweight and obesity rates. Future work could study the validity of these assumptions using an adequate dataset.

Despite these caveats, the study provides a clear picture of the impacts of a twenty percent increase of maize prices on selected nutrition outcomes of the Tanzanian adult population. However, we recognize that measuring changes in total calorie intake does not give all the necessary insights on the potential impacts of a price shock on the nutritional status of the population. The complementary relationships that we find between maize and micronutrient dense foods such as pulses, livestock or fruit and vegetables, indicate that the increase in the price of maize would also result in a fall of the consumption of these foods. This point suggests that further research is needed to analyze the impacts of a price shock from the perspective of the nutritional quality of food. Such a research could further reveal undernutrition and overweight aspects of malnutrition as well as micronutrient outcomes in order to assess the whole extent of the problem.

7 Conclusions

This paper evaluates the potential impact of a twenty percent maize price increase on calorie intake and its resulting incidence in the body weight in terms of the BMI in Tanzania´s adult population and therefore in the change of underweight, overweight and obesity rates used as proxies for aggregate nutritional outcomes.

All results exploit the National Panel Survey of 2010/11. Methodologically, we first estimate a food demand model that allows us to undertake the calorie-to-weight simulation. The QUAIDS model we use adequately captures consumers' behaviors by disentangling expenditure on necessity as opposed to luxury goods and capturing both the substitution and income effects of a price increase of maize. We then account for the inequitable intra-household redistribution of calories as a result of the price shock. Finally, we transpose the change in calorie intake into weight changes based on a static and a dynamic model concluding that in the context of this study the dynamic model proposes more realistic and convincing weight change patterns.

We find an increase of undernutrition and a decrease of overnutrition as a result of an increase in the price of maize, the main food staple in Tanzania. We conclude that this nutrition pattern is due to the limited substitution possibilities in a country such as Tanzania. We further suggest that the country could be undergoing an early stage of the nutritional transition as is the case of other low- and middle-income countries.

More precisely, the results reveal that households in Tanzania still rely to a great extent on maize consumption as the primary source of calories, and are therefore quite vulnerable to an increase in its price. It appears that the main aim of households in the face of a price increase is to meet their energy requirements under two main constraints (i) the substitution relationships of maize are restricted to other energy-dense foods with a low content in micronutrients, and (ii) the complementary relationships comprise protein and micronutrient rich foods. In the current production and market context of Tanzania, the substitution possibilities that would be necessary to compensate a lower consumption of maize are not enough to avoid the large fall of calorie intake and the subsequent drop of average weight. As a consequence, the prevalence of underweight rises resulting in increased undernutrition in terms of calories as well as micronutrients.

However, our results suggest that the impact of the increase in maize prices would only increase undernutrition, while the overweight and obese individuals would actually improve their nutritional status, even if it is only from the perspective of calorie intake. Even though we find a positive impact in the overweight and obesity rates in terms of calorie consumption, the intake of micronutrient rich foods would be reduced.

Moreover, we do find an indication of changing food consumption habits towards the distinctive dietary patterns of an early stage of the nutrition transition when comparing the dietary patterns of the overweight and obese individuals to those of the rest of the population.

We conclude that a maize price increase could not only negatively impact the prevalence of underweight in terms of calorie intake, but also the prevalence of overweight and obesity considering the current trends in dietary patterns. In the early future, policies will need to address simultaneously undernutrition and over nutrition, as well as promote the availability, access and utilization of more nutritious foods as the nutrition transition progresses.

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Appendix. A dynamic model for calorie loss

Dynamic models that take into account these factors and provide more reliable estimates of body weight changes have been developed (Ruff and Zhen, 2015). According to Hall et al. (2011), if we know calorie change, weight and fat mass, changes in fat and lean tissue masses can be approximated by the following equations:

$$\rho_F \frac{dF}{dt} = (1-p)(I-E); \qquad \rho_L \frac{dL}{dt} = p(I-E) \tag{1}$$

where F is fat mass, L is lean tissue mass, I is energy intake rate and E is energy expenditure rate. $\rho_F =$ 39.5 MJ/kg and $\rho_L =$ 7.6 MJ/kg are parameters that measure the energy per unit change of fat and lean tissue and p is a dimensionless function that partitions between fat and lean tissue among body composition (Hall et al., 2011). Following Hall et al. (2011) and Lin et al. (2011) we estimated the initial fat mass using the Jackson et al. (2002) gender specific equations and the coefficients of the regression that accounts for race, appropriate to Tanzania´s population.

$$\begin{aligned} F_m &= \frac{weight}{100}[0.14 * age + 37.35 * lnBMI - 104.21] \\ F_w &= \frac{weight}{100}[0.15 * age + 38.67 * lnBMI - 97.11] \end{aligned} \tag{2}$$

The initial lean mass was estimated as the difference between weight and initial fat mass. The total energy expenditure rate was defined by the following equation:

$$E = K + \gamma_l L + \gamma_f F + \delta weight + \beta \Delta I + \eta_F \frac{dF}{dt} + \eta_L \frac{dL}{dt} \tag{3}$$

where the parameters $\gamma_l = 92$ KJ/kg/day and $\gamma_f = 13$ KJ/kg/day are the regression coefficients for the resting metabolic rate to lean tissue mass and fat mass respectively, the parameters η_F =750 KJ/kg and η_L =960 KJ/kg account for the biochemical efficiencies associated with fat and protein synthesis, the parameter $\beta = 0.24$ accounts for the thermic effect of feeding and other physiological adaptations that affect energy expenditure when experiencing changes in energy intake (Hall et al., 2011) and δ is physical activity which is a function of the PAL and the ratio of the resting metabolic rate to weight. The PAL was assumed to be 1.7 and the resting metabolic rate was estimated using the Mifflin and St Jeor equations (Mifflin et al., 1990). As already mentioned, once we estimate the weight changes we apply them to the initial body weights observed in the survey for each household member and predict the counterfactual weights after the price shock. The static and dynamic calorie to weight models were performed on a daily basis over a year's time by running the models recursively. Results are reported over 3, 6, 9 and 12 month's period for comparability purposes. Finally, since the dynamic model we apply has been originally developed by Hall et al. (2011) and Lin et al. (2011) for adult subjects, we restrict the analysis to the individuals above eighteen years of age.

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1969/70 wurde durch Zusammenschluss mehrerer bis dahin selbständiger Institute das **Institut für Agrarökonomie** gegründet. Im Jahr 2006 wurden das Institut für Agrarökonomie und das Institut für Rurale Entwicklung zum heutigen **Department für Agrarökonomie und Rurale Entwicklung** zusammengeführt.

Das Department für Agrarökonomie und Rurale Entwicklung besteht aus insgesamt neun Lehrstühlen zu den folgenden Themenschwerpunkten:

- Agrarpolitik
- Betriebswirtschaftslehre des Agribusiness
- Internationale Agrarökonomie
- Landwirtschaftliche Betriebslehre
- Landwirtschaftliche Marktlehre
- Marketing für Lebensmittel und Agrarprodukte
- Soziologie Ländlicher Räume
- Umwelt- und Ressourcenökonomik
- Welternährung und rurale Entwicklung

In der Lehre ist das Department für Agrarökonomie und Rurale Entwicklung führend für die Studienrichtung Wirtschafts- und Sozialwissenschaften des Landbaus sowie maßgeblich eingebunden in die Studienrichtungen Agribusiness und Ressourcenmanagement. Das Forschungsspektrum des Departments ist breit gefächert. Schwerpunkte liegen sowohl in der Grundlagenforschung als auch in angewandten Forschungsbereichen. Das Department bildet heute eine schlagkräftige Einheit mit international beachteten Forschungsleistungen.

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