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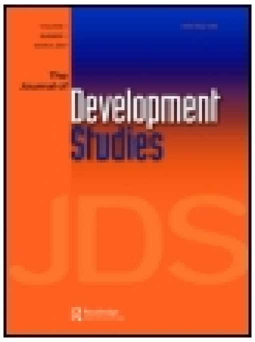
2 authors:

Luca Tiberti
Laval University

Marco Tiberti
World Bank



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Food Price Changes and Household Welfare: What Do We Learn from Two Different Approaches?

LUCA TIBERTI* & MARCO TIBERTI**
*Partnership for Economic Policy (PEP), Université Laval, Québec, Canada, **The World Bank, Development Data Group, Rome, Italy

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ABSTRACT *The use of a marginal approach can significantly distort the predicted effects of large price variations on monetary welfare over the medium- to longer-term. This paper aims at shedding some light on the differences between a marginal approach and a non-separable agricultural household model with behavioural responses. When behavioural adjustments are allowed, households can adapt their consumption and production patterns by resulting in lower deteriorations in household welfare. The second-order effects introduced in the approach with responses reduce the negative effects due to the first-order consumption effects, with significant differences across quintiles. On average, the second-order effects represent up to roughly 40 per cent of total first-order effects.*

In the last decade the world prices of many staple food commodities have increased impressively, experiencing large spikes in three circumstances and raising widespread concern about the potential impacts on households' welfare in poor countries. In 2007–2008 the World Bank Food Price Index rose by 60 per cent in few months; after a significant decrease in 2008–2010, the World Bank Food Price Index increased sharply reaching its 2008 peak in early 2011. Then, in mid-2012 the World Bank Food Price Index exceeded its 2008 and 2011 peaks (World Bank, 2014).

The potential impacts of food price increases on household welfare in poor countries depend on the price transmission path to overall commodities and netputs, as well as on the country's economic structure (Ravallion & Lokshin, 2004). Indeed, in developing countries, while on the one hand the poorest spend about three quarters of their incomes on food commodities (Cranfield, Preckel, & Hertel, 2007), on the other hand, farm households, which are often among the poorest groups, may benefit from higher food prices or, at least, partially offset the negative effect of higher prices. Thus, the impact of higher food prices on farm households' welfare depends on their net sales of these goods and on the adjustment in consumption and production behaviours.[1] The effects also generally differ depending on the time horizon we look at (that is, immediate to short-term impact versus medium- to longer-term effect).

While most of the existing literature analyses first-order and immediate effects of price increases on expenditure and supply patterns, or – less frequently – second-order effects on consumption (that is allowing for adjustments in consumption), there are few studies taking into account the substitution effects in both consumption and production (Ferreira, Fruttero, Leite, & Lucchetti, 2013). This distinction crucially depends on the time horizon of the analysis and the size of the price increase. For determining the instantaneous effects, the first approach can be more appropriate, while the

Correspondence Address: Luca Tiberti, Partnership for Economic Policy (PEP), Université Laval, Pavillon J-A DeSève, G1V 0A6 Québec, Canada. Email: luca.tiberti@ecn.ulaval.ca

framework including the second-order effects is generally more suitable for longer runs (medium- to longer-term). Also, for relatively small price changes, the first-order approach can well approximate the welfare effects, even in a longer-term. For larger price variations, including second-order effects is recommended. Henceforth, the two approaches may differ in their scope and can have different policy implications.

In this article we discuss the welfare effects due to cereal price increases under two different theoretical frameworks. First, we follow the approach initially proposed by Deaton (1989), which we call the *marginal* approach. This approach assumes no responses in consumption and production behaviours by households. Second, by assuming non-separability (motivated by failure in the labour market – see below for more discussion), we allow households to adapt their consumption and production behaviours as a consequence of food price changes (we call this approach *response* method hereafter). Both approaches can be broadly categorised under the agricultural household models (AHMs) family (as originally proposed by Singh, Squire, & Strauss, 1986), in the sense that households are considered either as net consumers or net producers. But they differ in the way households are allowed to adjust their behaviours following an external price shock: no adjustment is assumed under the *marginal* approach (so more suitable for the short-term) while adjustment in various behaviours (consumption, production and labour/leisure choice) is allowed in the *response* model proposed here (so more indicated in the medium to longer run for large price changes). In addition, the *marginal* model assumes that consumption and production decisions are taken independently and that labour market choices are not affected by such decisions, whereas under the *response* non-separable approach consumption, production and labour market decisions by farmers are taken jointly as a result of maximisation of households' utility. The approach developed by Deaton is still the reference and the most adopted tool to assess the welfare impact due to price variations in developing countries. As acknowledged in the literature, it is useful to stress that such an approach 'refers to the impact of marginal changes in prices on household welfare, holding everything constant' (Glewwe, Agrawal, & Dollar, 2004, p. 171). In other terms, this is an analytical tool appropriate just for 'infinitesimal price changes' (Ferreira et al., 2013, p. 4), as also shown in Deaton (1989, p. 23) where a 1 per cent increase in rice price is applied. The food price changes observed since 2007 and for many consecutive months after were not marginal; despite that, as discussed below, many studies assessing the welfare effects of that recent food crisis adopted the marginal approach. As asserted in Robles and Torero (2010, p. 118), the 'substitution effects are far from negligible given the size of the observed food price changes'. The objective of this work is to show and discuss the differences emerging between a marginal and response approach, for a large range of cereal price change. Depending on local market failures, adjusting consumption and production behaviours can take some time. So, one can argue that the marginal approach is more appropriate for immediate-term impacts, while the response framework can be better for the medium-term effects. However, it is worthy to stress that some of the response changes can be immediate as can be the case for consumption decisions[2] (see Ivanic & Martin, 2014, for a discussion on short- and long-term effects).

The *illustrative* applications of the two methodologies are carried out on data from Tanzania collected in 2008/2009. The welfare effects under the two approaches are estimated over a range of price changes between 1 per cent and 132 per cent. This range, which is used just for our illustration below, was observed in Tanzania between 2008 and 2012 (when cereal prices peaked at their highest value). Also, we assume that consumers and producers face full price transmission.

We first estimate the required compensation needed to households to maintain their initial level of real welfare (that is before the price rise) under the two different approaches and decompose the welfare change into the first- and second-order consumption and production components. We then predict the poverty effects through the standard incidence and the depth of poverty (FGT0 and FGT1), and decompose the poverty changes into the growth and distribution components, and by consumption and production contributions as well by direct and indirect effects. Significant differences emerge between the two approaches: the welfare effects are substantially more negative under the *marginal* approach than under the *response* framework as the second-order effects play an important mitigating role, whose size and trajectory can differ across quintiles. Also, the growth and distribution components drive poverty variations differently according to the adopted approach.

We are aware that our framework is in partial equilibrium in that we consider only the impacts of changes in the prices of staple foods on households, by thus omitting possible general equilibrium effects (for example, changes of wages and shifts of employment across different sectors, as well as in other commodities, outputs and inputs prices) which normally follow after significant price changes. Nevertheless, in our opinion, modelling the behaviour of consumption and agricultural production may provide useful insights in assessing the effects of food price changes in poor and agriculture-based countries, especially under large price changes.

The main contribution of this article is then to discuss the welfare and poverty effects due to food price rises as estimated under a *marginal* and a *response* approach, and to disentangle the total effect into first- and second-order consumption and production effects.

1. A brief review of the literature on welfare effects of food price changes

Food price changes may have first- and second-order effects on household welfare at a range of scales.

At the national level, food price changes may affect local commodity markets (Rapsomanikis, Hallam, & Conforti, 2006), local labour markets (Headey, Nisrane, Worku, Dereje, & Taffesse, 2012), fiscal balance (Albers & Peeters, 2011) and terms of trade (Allen & Giovannetti, 2011).

The effect of food price changes on households is heterogeneous and depends on their market position and their geographical location. Indeed, net food-selling and net food-buying households are likely to experience an opposite welfare effect following food price increases. Household welfare is directly affected by changes in food prices through the variation in their purchasing power and the net profit from farming activities. Hence, urban and landless rural households are expected to face more pronounced reductions in welfare as a consequence of rising food prices (Caracciolo, Cembalo, Lombardi, & Thompson, 2014; Minot & Dewina, 2015). In addition, food price increases can induce households to reduce their food consumption (or change their composition of food consumption) and then generating longer-term (and, sometimes, irreversible) nutrition impacts (Anríquez, Daidone, & Mane, 2013). Schooling and health choices can be similarly affected as a consequence of larger budget constraints, thus likely producing longer-term detrimental effects on human capital investment (Friedman & Sturdy, 2011). In addition, the prevailing real wage rates are influenced by commodity price changes and can directly affect household welfare. Wage rates usually adjust upward following food price increases, although such an adjustment is not immediate and does not normally fully offset the negative effect of rising food prices (Jacoby, 2013; Ravallion, 1990; Ravallion & van de Walle, 1991). Finally, households are indirectly influenced by the change in the Government's tax revenue that, in turn, can affect the provision of public services, and by the variation in the exchange rate, which can alter the relative price of tradable and non-tradable goods (Benson, Minot, Pender, Robles, & von Braun, 2013).

In this article we assess the partial equilibrium impact of food price increases on household welfare in Tanzania by focusing on the variation in their purchasing power and the net profit from farming activities. Such an impact has been largely investigated in developing countries and received renewed attention after the 2007–2008 food price crisis. Minot and Dewina (2015, Table 1) provide a detailed list of studies assessing the welfare impact of price changes.

Deaton (1989) developed a non-parametric method to estimate the effect of price changes on the distribution of welfare and applied this to rice prices in Thailand. He introduced the concept of *net consumption ratio*, defined as the difference between the consumption and production of rice over total expenditures. The *net consumption ratio* for a particular commodity represents the 'before-response' or impact elasticity of expenditures with respect to the price change of that commodity. Although with some differences, this remains the leading analytical tool of a number of studies about the welfare impact of price changes in developing countries (for example, Budd (1993) for Côte d'Ivoire; Barrett and Dorosh (1996)).[3]

Table 1. Net cereal sellers, cereal consumption and production ratios (of total consumption), national and by quintiles, per cent.

	Net sellers	Consumption ratio	Production ratio	Net consumption ratio
Farm Households				
Tot	16.47	25.30	9.08	16.23
quint 1	22.79	25.89	11.87	14.02
quint 2	19.08	27.90	11.43	16.46
quint 3	12.23	26.50	7.57	18.93
quint 4	14.97	24.34	7.24	17.10
quint 5	10.60	19.32	5.47	13.84
Whole Population				
Tot	11.78	24.33	6.46	17.87
quint 1	18.98	25.47	9.60	15.88
quint 2	15.29	27.13	9.15	17.97
quint 3	9.34	26.48	5.78	20.70
quint 4	10.84	24.30	5.24	19.06
quint 5	4.94	18.32	2.54	15.78

Notes: quint 1 refers to the poorest quintile, quint 5 refers to the wealthiest quintile.
Source: Authors' estimations using TNPS-1.

The worthiness of this method has been widely recognised. However, as noted by Ferreira et al. (2013, p. 5), 'it neglects substitution effects, both in consumption and in production, and it ignores general equilibrium effects of the price changes, including those that operate through labour markets'. In addition, the *marginal* approach ignores own-price effects on the consumption and production sides. As stated earlier, the Deaton's method is appropriate in the instantaneous run and for marginal price changes, where substitution effects can be reasonably approximated to zero. This is mostly the case in the very short-term.

Among partial-equilibrium studies, even the most recent ones which assess the 2007–2008 food price crisis are basically based on the net benefit ratio (NBR) as originally proposed by Deaton, that is without adjustments in consumption and production choices (see Benfica, 2014; Ivanic & Martin, 2008; Simler, 2010; Wodon & Zaman, 2010). Minot and Dewina (2015) consider adjustment effects and provide long-run estimates of price increases on household welfare fixing own-price demand and supply elasticities at non-unitary values (−0.3 and 0.3 respectively), while cross-price elasticities are hypothesised to be negligible (a very similar approach is employed by Klytchikova & Diop, 2006). Minot and Goletti (2000) include the response of consumers and producers to estimate the price effects following the trade liberalisation in Vietnam. In their study, demand elasticities are estimated through an Almost Ideal Demand (AID) System, while the supply elasticities estimates are based on an econometric analysis of time-series data and come from a different study. Robles and Torero (2010) instead estimate the substitution effects in consumption, but finally ignore reactions on the production side in their application. In order to estimate long-run effects, Ivanic and Martin (2014) develop a microeconomic simulation model accounting for changes in farmers' profits due to output price changes. Their model estimates the relationship between food price changes and wages, and simulate the marginal impact of price and wage rate changes on households' real income, by adding (differently from Deaton, 1989) a marginal effect on labour supply and demand due to a change in the wage rate.[4] Attanasio, Di Maro, Lechene, and Phillips (2013) take into account the possible substitution effects across food commodities due to price rise by estimating a Quadratic Almost Ideal Demand System (QAIDS) on data from Mexico. Similarly, Bibi, Cockburn, Coulibaly, and Tiberti (2009) simulate the welfare effects of the food price rise in Mali between 2006 and 2008 by estimating a QAIDS model for rural and urban households separately and considering the first-order effect of price changes on net agricultural profits. Finally, in a short-term analysis, a recent paper by Van Campenhout, Lecoutere, and D'Exelle (2015) revisits the methodology proposed by Deaton by taking into account seasonal price variations (thus, considering the timing of sales and purchases) and the spatial price heterogeneity in Southern Highlands of Tanzania with data from 2007 to 2008.

In contrast to the cited studies, this work relies mainly on the theoretical framework of agricultural household models (AHMs), which was reviewed and discussed systematically in Singh et al. (1986) and used in the past to assess the effects of food price changes on welfare (see, for example, Strauss (1984) in Sierra Leone). A recent application of such an approach is the work by Tiberti and Tiberti (2015), where a non-separable agricultural household model (AHM) – where consumption, production and labour decisions are jointly estimated and interlinked – was used to estimate the effect of price changes and rural policies on household welfare.

In this article, we follow the theoretical framework and estimation strategy proposed in Tiberti and Tiberti (2015) to estimate the impact of large price changes on households' welfare in a non-separable agricultural household model (AHM) framework when adjustments in consumption, production and labour/leisure choice are allowed. In contrast to Tiberti and Tiberti (2015), the scope of the present study is to discuss in-depth the differences between the *marginal* and *response* approach. The estimated divergences are assessed along the income distribution and by types of households, and different kinds of decomposition to identify the driving components of such divergences are performed.

The brief review above does not include studies based on a general equilibrium approach (CGE) (see, among others, Anderson, Cockburn, & Martin, 2011; Headey, 2014; Van Campenhout, Pauw, & Minot, 2013). As stated above, we are aware that ignoring general equilibrium effects may yield overstated ultimate impacts on household welfare, but we prefer to keep the discussion only at the microeconomic level. In any case, the two approaches proposed here could be used in a combined CGE-microsimulation model (for example top-down fashion).

2. Analytical framework, empirical approach and data

2.1. Marginal approach

Deaton (1989) introduced the concept of *required compensation* to estimate the effect of food price changes on household welfare. In Deaton's words, 'we can ask how much money (positive or negative) the household would require in order to maintain its previous level of living' (Deaton, 1989, p. 4). Said differently, the required compensation corresponds to the opposite of the welfare change due to a price variation of a given item.

Given the price change dp^v of commodity/output v, the required compensation for household h $dB_h^{p_v}$ can be formalised as

$$dB_h^{p_v} = (c_h^v - o_h^v)dp^v = p^v(c_h^v - o_h^v)d\ln p^v \tag{1}$$

where c_h^v is the consumption of v and o_h^v represents the production of v by the farm household.

The required compensation $dB_h^{p_v}$ can be expressed as a fraction of the total household expenditure y_h as

$$(dB_h^{p_v}/y_h) = (w_h^v - s_h^v)d\ln p^v \tag{2}$$

where $w_i = p^v c_h^v/y_h$ is the budget share of commodity v and $s_i = p^v o_h^v/y_h$ is the share of production value of output v. It is worth noting that $(w_h^v - s_h^v)$ is what Deaton calls the *net consumption ratio*, and can also be defined as the elasticity of the equivalent income with respect to the price of good v.

Thus, the effect of price changes depends on the net position of the household on the market (that is the household can either be a net producer or a net consumer of a given good). Analysing the ratio $(dB_h^{p_v}/y_h)$ along the income distribution informs us about how a change in prices affects households at different percentiles. With such an approach, households are assumed to keep their production and consumption behaviours unchanged following a price change, that is without substitution effects. As said earlier, these hypotheses mainly rely on the assumption that price changes are marginal (or, infinitesimal) and is generally appropriate for the very short-term.

2.2. Response approach[5]

In order to take consumption and production decisions into account, the approach proposed in this study is based on the analytical framework of AHMs initially developed by Singh et al. (1986), where non-separability between consumption, production and labour choices is assumed. In particular, in a context with imperfect or missing markets, consumption, production and labour decisions are interlinked and exogenous shocks can affect the time allocation of individuals by endogenously changing the shadow wage (De Janvry, Fafchamps, & Sadoulet, 1991).[6] We consider this approach more appropriate to analyse farmers' behaviour, and in particular production and consumption decisions with missing markets. In rural Tanzania labour accounts for most inputs used in farm production (about 70% of total variable inputs) and the labour market is very thin; this justifies the choice of using a non-separable AHM.[7] The hypothesis of separability was also tested and rejected on the same data in an earlier study (see Tiberti & Tiberti, 2015). With this specific approach, the price effect on welfare can be decomposed into first- and second-order effects. In addition, under a non-separable framework, the second-order effects can in turn be the result of direct and indirect components, with the first capturing the consumption or production adjustments due to the exogenous price change and the second being the consumption or production adjustments due to the endogenous change in the shadow wage as generated by the exogenous price shock. As stated earlier, this framework is in partial equilibrium, and (endogenous) changes in prices (such as market wages and other commodities or netputs) and in volumes (such as employment) in all economic sectors are not captured here.

Broadly following Henning and Henningsen (2007a, 2007b), we estimate a static non-separable agricultural household model (nsAHM). To do that, we adopt a two-stage estimation strategy where first we estimate the shadow price of labour and, in the second stage, the estimated shadow price is used to estimate the consumption, production and labour behaviours. The estimated shadow wage is used as price of the labour input in the production module and as price of the leisure commodity in the consumption model, as well as to estimate the labour cost and income functions. A Cobb-Douglas production function is estimated to derive the shadow price of household labour (see, for example, Jacoby, 1993). The consumption-related parameters are derived by estimating an Almost Ideal Demand System (Deaton & Muellbauer, 1980); this is done separately for farm and non-farm households as their adjusting capacity can differ. For the production module, starting from a translog multi-input multi-output profit function we estimate a system of equations derived from a profit-maximisation specification (see, for example, Fulginiti & Perrin, 1990), while the parameters associated with the labour choices are estimated through an extended Heckman (switching regression) approach controlling for fixed, proportional and non-proportional transaction costs.[8] The consumption and production elasticities are next calculated based on the parameters obtained from the previous estimations, while the shadow wage elasticity with respect to the price of cereals is estimated through comparative statics as normally done in the AHM literature. These elasticities are finally used to estimate the second-order price effects on household welfare. It should be noted here that, because we use one cross section data, our production-related price elasticities can be considered as medium-term (possibly up to one year, depending on the biological agricultural seasons) elasticities and do not capture long-term adjustments[9] (which are generally larger) (see Ivanic & Martin, 2014, for more discussion on that).

Following Robles and Torero (2010),[10] the required compensation for household h due to the variation in the price p of commodity/output v ($dB_h^{p_v}$) is given by:

$$dB_h^{p_v} = \underbrace{\left[w_h^v y_h \frac{dp_v}{p_v} - s_h^v y_h \frac{dp_v}{p_v}\right]}_{first-order} + \underbrace{\frac{1}{2}\left[\sum_i w_h^i \Theta_{iv}^{nsAHM} y_h \left(\frac{dp_v}{p_v}\right)^2 - \sum_n s_h^n \varepsilon_{nv}^{nsAHM} y_h \left(\frac{dp_v}{p_v}\right)^2\right]}_{second-order} \tag{3}$$

where $w_h^{\cdot}$ and $s_h^{\cdot}$ are the share of commodity $v, i \in I$ and the share of product $v, n \in N$ over total household expenditure y; $\frac{dp_v}{p_v}$ is the percentage change in the price of commodity/product v; Θ_{iv}^{nsAHM} and ε_{nv}^{nsAHM} are the price elasticities under the non-separable framework (as estimated below) for consumption and production respectively. The first-order component is equivalent to the required compensation derived through the *marginal* approach (as obtained in Equation (1)). As evident, the marginal approach assumes that the own- and cross-price elasticities of production and consumption are equal to zero. The second-order component estimates the effects on required compensation due to production and consumption changes. In particular, when a nsAHM is used, the production and consumption elasticities are obtained respectively as (see Tiberti & Tiberti, 2015, for full details on their derivation):

$$\varepsilon_{nv}^{nsAHM} = \varepsilon_{nv}^{sAHM} + \varepsilon_{nL}\psi_{p_v} \tag{4}$$

and

$$\Theta_{iv}^{nsAHM} = \Theta_{iv}^{sAHM} + \Theta_{iL}^{H}\psi_{p_v} \tag{5}$$

As is commonly done in the AHM literature, the comparative statics of nsAHM is the sum of the direct effects on production and consumption behaviours due to an exogenous price change and the indirect effects on production and consumption decisions due to the endogenous change in the shadow wage subsequent to the change in exogenous prices. The direct effects on production and consumption choices are captured by the standard own- and cross-price elasticities under a separable approach (ε_{nv}^{sAHM} and Θ_{iv}^{sAHM} for consumption and production, respectively). The indirect effects correspond to $\varepsilon_{nL}\psi_{p_v}$ and $\Theta_{iL}^{H}\psi_{p_v}$ respectively, with ψ_{p_v} being the elasticity of the shadow wage with respect to the price of product/commodity v, ε_{nL} the price elasticity of product n with respect to the price of labour L, and Θ_{iL}^{H} the Hicksian price elasticities with respect to the price of leisure L.

The elasticity of the shadow wage (ψ_{p_v} – defined in the Appendix) depends on the impact on time allocation of the change in the shadow wage (as captured by the denominator in Equation (A1) in the Appendix) and in the exogenous price (identified by the numerator in Equation (A1) in the Appendix). Its size crucially depends on the degree of labour market imperfections (which is captured by the $\left(\varphi_L^h X_L^h - \varphi_L^s X_L^s\right)$ in the denominator), ranging from the case where the labour market is perfect (in such a situation we fall back to the case of a separable model and the elasticity is zero) to where the labour market is missing (in such a case labour heterogeneity and the non-proportional transaction costs are infinitely high, and we are in a autarkic regime).

Table A1 reports the price elasticities for the shadow wage, netputs and commodities for farmers (then including the non-separable component) and for non-farmers, as well as the income elasticity derived from the consumption system. The estimated parameters take the expected sign. In particular, we are interested into the parameters entering in Equation (3). We start with farmers. The own-price elasticity of the cereals output is relatively low and not statistically significant. As also reported in other studies, we find a complementarity between the production of cereals and inputs, and other crops. In particular, as shown for some outputs in Fulginiti and Perrin (1990), Antle and Aitah (1986) and Weaver (1983) in the long-run, the cross price elasticity of other outputs is larger than the own price elasticity. In the Tanzanian case, as discussed in Tiberti and Tiberti (2015), this might be due to the decision by the household to consume less cereals (whose relative price is increased) and to produce more of other outputs for consumption purposes. As stated in Sadoulet and De Janvry (1995) cross-price elasticities' sign is indefinite. Finally, the demand for inputs rises when the price of cereals increases to satisfy the larger production. Moving to the consumption component, all price elasticities are statistically significant, with the exception of that associated to commodity 2. For non-farmers, the only relevant parameters are those related to the consumption component. The price elasticities of commodities demand are all statistically significant and, for goods 2 and 3, differing substantially from those estimated for farmers.

2.3. Data

The application of the two methods is carried out with data from Tanzania collected in 2008/2009 (Year One National Panel Survey Integrated Households Survey [TNPS-1]), implemented by the Tanzania National Bureau of Statistics (Government of Tanzania [GoT], 2010) between October 2008 and September 2009. The survey is nationally representative and surveyed 3265 households (2063 households in rural areas and 1202 urban areas), with 75 per cent of them having agriculture as their main source of livelihood. The questionnaire collects detailed information on households' consumption and agricultural production. This study uses the whole sample (that is 3265 households) for the consumption analysis, but only 1931 households (of which around 10% live in urban areas) are finally retained for the production analysis (either because they did not own land or they did not cultivate any crop in the 2008/2009 long rainy season). For the analyses presented below, the new vector of real household consumption – estimated by adding the required *marginal* or *response*-derived compensations to the original household consumption – is converted into per-adult equivalent terms (according to the differences in caloric needs by age and gender), deflated by the Fisher price index (which takes spatial and temporal price differences into account) and then compared to the 2008 monthly poverty line of 18,007 Tanzanian shillings (as estimated by the World Bank).

3. Price changes simulations and poverty estimates

In this section we discuss the impact of food price changes on household welfare by providing a comparison between the *marginal* and *response* approach estimates.

According to existing data,[11] Tanzania showed the lowest cereal prices over the second half of the 2000s in May 2007. Since then, cereals' prices started to rise rapidly. As an illustrative application of the two methods proposed in this study, we simulate a price increase of cereals between 1 and 132 per cent, which is the price change experienced between end-2008 (when the survey we use started) and 2012.[12] During the food price crisis, year-to-year changes in cereals' prices are generally similar or even higher (for example, between February 2007 and February 2008). In both *marginal* and *response* approaches (Equations (1) and (3) above), we assume that marketing margins between producer and consumer prices are proportional. As noted by Minot and Dewina (2015), if we assume that marketing margins are fixed in real terms, then the relative change in producer prices is larger than the relative change in consumer prices and the welfare impact is more positive (or less negative). Assuming fixed marketing margins probably yields even larger discrepancies between the *marginal* and *response* estimates.

The large majority of the Tanzanian population is a net buyer of cereals. A portrait of the patterns of cereal consumption and production is given in Table 1. About 16.5 per cent of individuals living in farm households[13] is a net seller, decreasing to around 11.8 for the whole population.[14] On average, about a quarter of total household budgets are spent on cereals, which translates into a likely greater impact on household welfare following an increase in the price of cereals. Cereals production is generally not large enough to protect households from higher prices; on average, for farm households, cereals production represents about 9 per cent of the total expenditure (this rises to around 12% for the poorest quintile). Although with some differences, the net consumption ratio (defined as the difference between the cereals consumption and production shares) does not differ substantially across the income quintiles, with the third quintile showing the relatively largest share while the richest group has the lowest ratio, closely followed by the first quintile. As defined in the *marginal* approach described above, the net consumption ratio is the price elasticity of the cost of living. As depicted from Table 1, a 1 per cent increase in the price of cereals corresponds to a deterioration in the household welfare by around 0.18 per cent (around 0.16 per cent for farm households). Or, equivalently, for a 1 per cent increase in the price of cereals, an increase by 0.18 per cent in the household income is required to allow individuals to enjoy real welfare at the pre-price increase level.

Using non-parametric estimations, Figure 1 shows the required compensation as estimated by the *marginal* and *response* methods after a 75 per cent[15] increase in the price of cereals.

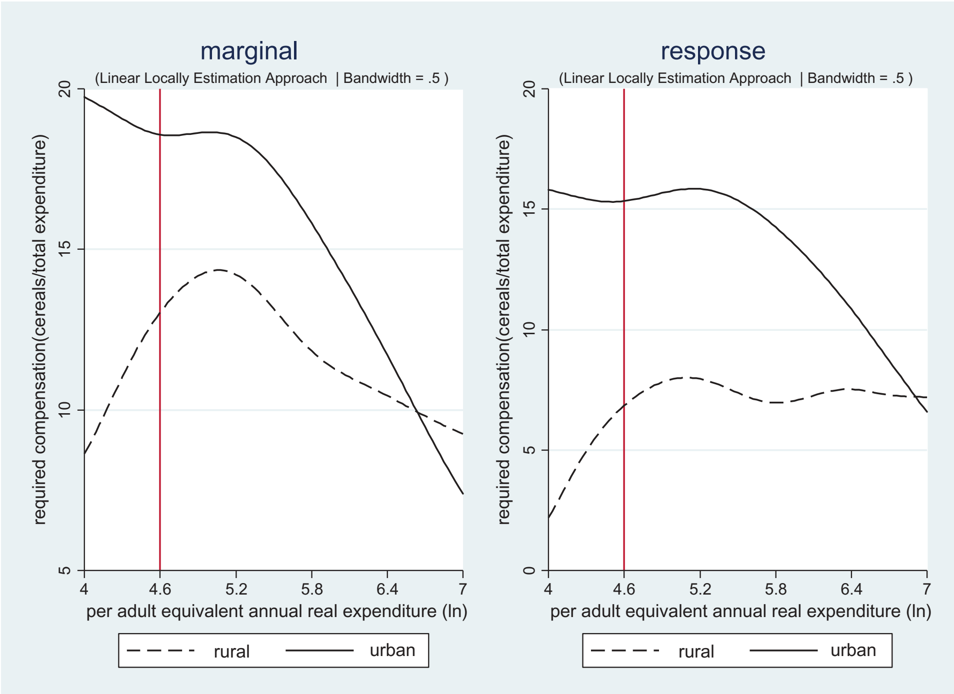

Figure 1. 75 per cent cereals price increases required compensations (in %).
Notes: The vertical line represents the national poverty line; non-parametric estimations with DASP (Araar & Duclos, 2007) – linear locally estimation, bandwidth = 0.5
Source: Authors' estimations using TNPS-1

This figure allows us to straightforwardly understanding how the welfare impact differs in the whole population according to the two approaches. According to the *marginal* method-based estimates, urban households lying around the poverty line would need about an 18 per cent increase of their income in order to enjoy the same real income as before a 75 cereals price increase, while according to the *response* estimates they would need about 15 per cent. Rural households around the poverty line result to be less affected and should be compensated with 13 and 7 per cent according to the *marginal* and *response* approach respectively.

The pattern of the impact is not much different between the two methods, but some significant divergences result between the *marginal* and the *response* required compensation, with the latter being lower. As expected, when adjustments are allowed, households adapt their consumption and production patterns by resulting in significantly lower deteriorations in household welfare. As evident from Figure 1, overall consumption and production adjustments in rural households (of which 83% are farmers) allow for larger cushioning effects, therefore reducing the welfare loss. As expected (not shown here), the differences are minimal for small price changes (for example 1%) while they widen substantially when price variations are larger (for example 132%), and the distance between urban and rural areas increases as price changes grow.

Following a cereal price increase, consumers are expected to divert their expenditure from cereals towards less expensive commodities, while farm households are incited to increase the production of cereals with some repercussions on the other products as well. The size and the sign of such adjustments depend on own and cross price elasticities of the demand for commodities and production of outputs (see Table A1 in the Appendix). While the consumption (for both farmers and non-farmers) and production of cereals are relatively inelastic to their own price increases (own elasticity lower than one in absolute value – cereals are a largely consumed and own-produced good in Tanzania), a larger price of cereals induces a more than proportional rise in the production of other crops[16] and, though

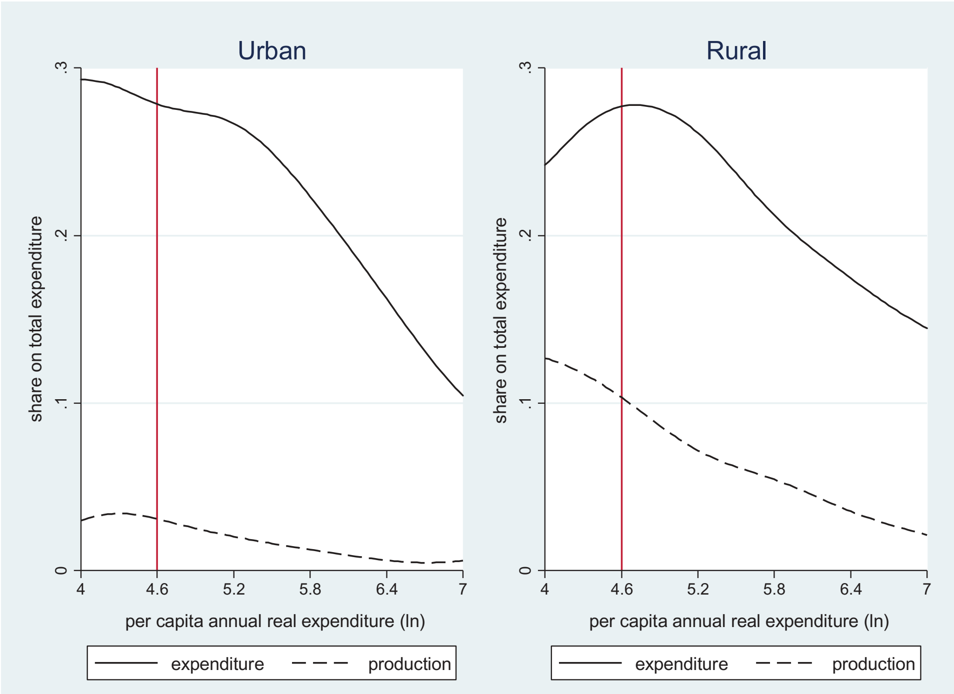

Figure 2. Cereals expenditure and production ratios on total consumption, by urban/rural areas.
Notes: non-parametric estimations with DASP (Araar & Duclos, 2007) – linear locally estimation, bandwidth = 0.5.
The vertical line identifies the national poverty line.
Source: Authors' estimations using TNPS-1

small, a larger consumption of other crops.[17] Henceforth, changes in consumption and production behaviours allow households to mitigate or increase welfare losses due to cereals' price change depending on households' net position.

Figure 1 also clearly depicts that in urban areas the most affected households are those lying below the poverty line while in rural areas poorest households are generally less affected. This is expected as poorest urban households devote about 30 per cent of their total budget to cereals combined with practically no production (see Figure 2). In contrast, the poorest households in rural areas show a slightly more diversified consumption of food and, more importantly, their production of cereals represents more than 10 per cent of their total expenditure. However, the production of cereals is on average not as large as their consumption, such that an increase in the price of cereals is still expected to deteriorate substantially the welfare of households living in rural areas. As already shown in Figure 1, given urban and rural households' consumption and production patterns, the price impact along the income distribution differs much more in urban than in rural areas.

Figure 3 shows the average required compensation as estimated through the *marginal* and *response* approaches following cereals price increases between 1 and 132 per cent. In particular, we report the required compensation estimated for the whole population and for the different quintiles.

Again, it clearly appears that the *marginal* required compensation is considerably higher than the *response* required compensation and that the gap increases as cereals price changes are larger. On average, the required compensation estimated through the *marginal* approach is up to about 24 per cent in correspondence with a 132 per cent increase in the price of cereals, compared to around 8 per cent under the *response* framework (Figure 3). For large food price shocks which occur over the medium- to long-term (as the ones observed in 2006–2008 where food prices increased continuously month after month for about two years), the use of the *marginal* approach can lead to substantially overestimated effects on household welfare and wrongly inform the policy-maker about the effects of

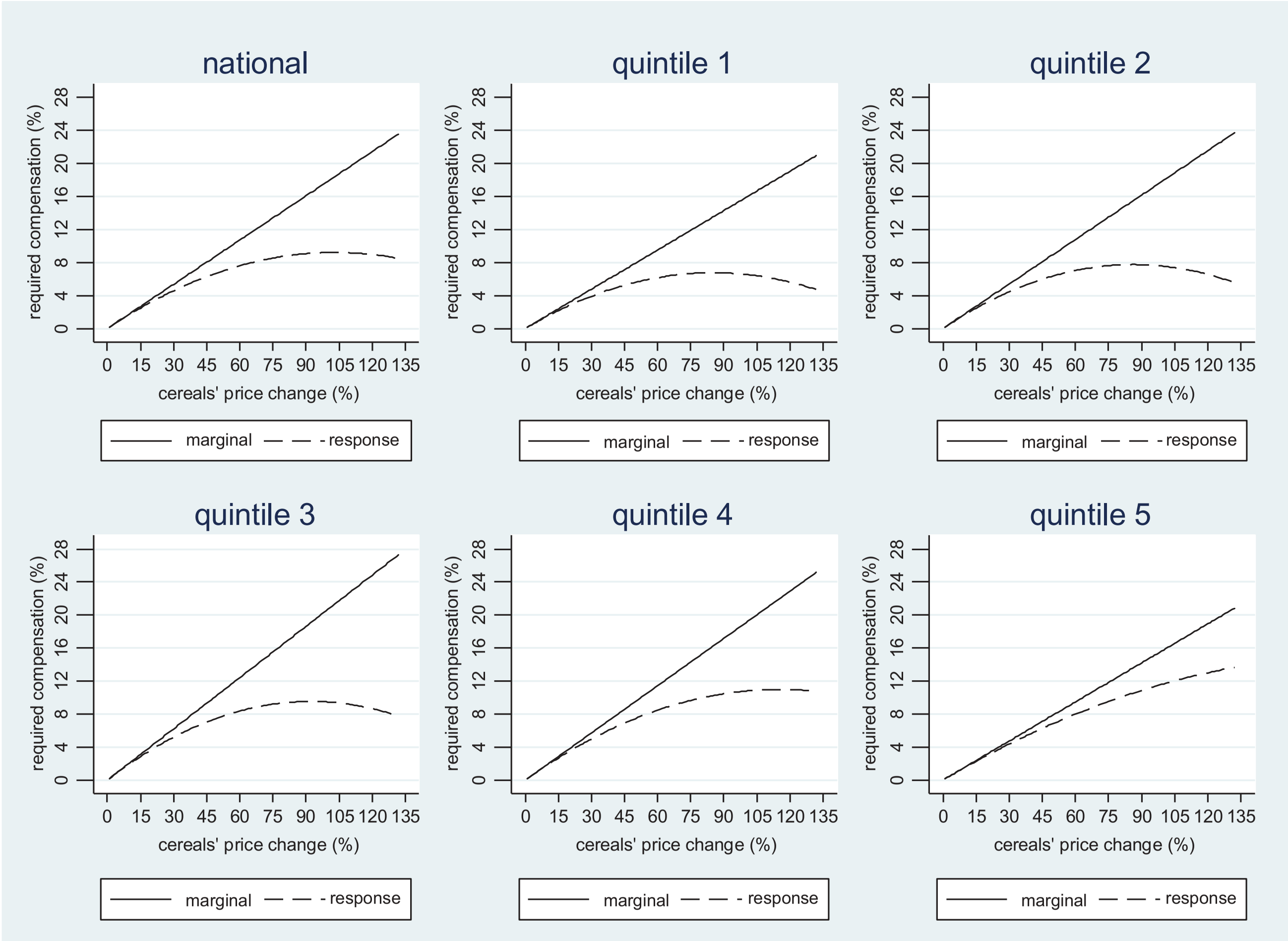

Figure 3. *Marginal* and *response* required compensation, national and by quintiles.
Notes: quintile 1 refers to the poorest quintile, quintile 5 refers to the wealthiest quintile.
Source: Authors' estimations using TNPS-1.

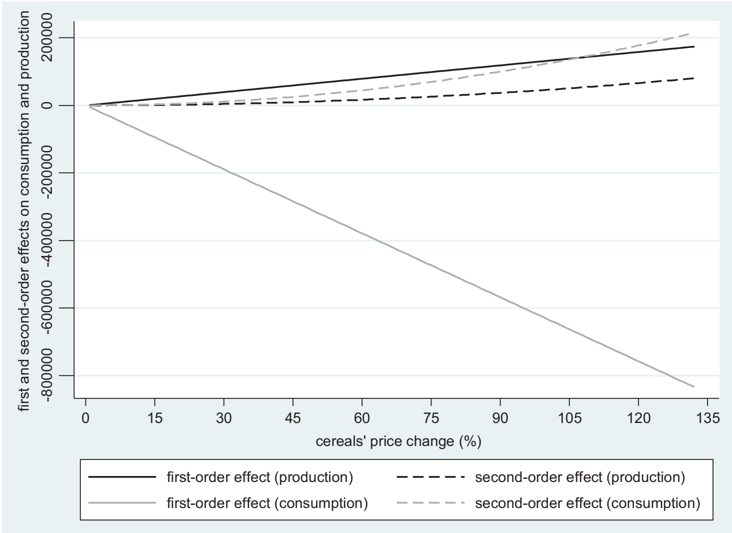

Figure 4. Non-AHM – consumption and production effects (first- and second-order).
Source: Authors' estimations using TNPS-1.

food price rise. As expected, the required compensation-price relationship under the *marginal* method is linear, whereas under the *response* approach takes a concave shape with the highest value at around 100 per cent price rise. As expected, when the analysis is run separately by cereal producers and non-cereal producers (not shown here due to lack of space), *marginal* and *response* curves for non-producers are much closer and the difference in terms of the required compensation becomes relatively important only for large price changes and reaches up to 5 percentage points (national figures) when the price varies by 132 per cent. Conversely, for cereal producers the difference between the two approaches is significantly larger than the one shown in Figure 3.

The disaggregation of the different components affecting the change in the required compensation clearly shows the differences between the patterns of two approaches (see Figure 4). While the *marginal* approach is affected uniquely by the first-order consumption and production effects (which are both associated linearly to the cereals price rise), the *response*-based estimates are the result of the first and second-order consumption and production effects. The consumption and production responses follow a convex pattern with respect to the price, with the former growing faster starting from about a price increase by 40 per cent. These *response* effects (and the consumption one in particular) explain the concave shaped pattern of the required compensation when households are allowed to adjust their behaviours. This graph is a good depiction of the extent to which the two approaches differ. As expected, the largest (negative) effect on household welfare and on poverty comes from the first-order (without adjustments) change of consumption. On average, household consumption decreases by about 800k Tanzanian Shillings (TZS) when cereals price variation is 132 per cent (straight grey curve in Figure 4). When the positive first-order effects associated with the production are plugged in (as in Deaton, 1989), the average change in household consumption decreases to up around −600k TZS (straight black curve), then leading to a first-order positive contribution of cereals' production of about 200k. If we take the *response* effects of consumption into account, the maximal gain is slightly more than 200k TZS (grey dashed curve), which contributes to an additional improvement in household consumption. The total net effect on household consumption would then be a reduction by up around 400k. Finally, when the second-order effects of production are considered an average gain by up around 50k TZS is simulated (black dashed curve), which translates into a total net variation in household consumption by around −350k TZS (which corresponds to an average reduction of household consumption by 55%). The second-order effects represent up to roughly 40 per cent of the first-order effects. As evidence, when only the first-order effects of consumption are included, the negative effects on household welfare due to large food price changes observed over the medium- to longer-term can be significantly overestimated. It is worth noting here that the response-related components (especially the one associated with production) can take longer than the marginal components to occur because households may need some time to adjust their behaviours, so it is important to set the time horizon of the price change.[18]

Some significant differences emerge across quintiles as reflected by their different consumption and production patterns (as discussed above) (Figure 3). According to the *marginal* approach, as expected from Table 1, the most affected households are the middle-income classes (the third quintile followed by the forth one). The required compensation for the third quintile is up around 28 per cent compared with around 20 per cent for the poorest and richest quintiles. According to the *response* approach, the required compensation needed to the poorest quintile would be just up to less than 6 per cent (for a 70% price increase) and slightly more than 4 per cent when prices increase by 132 per cent.[19] The poorest quintile is largely represented within farmers, then being generally more able to adjust their consumption and production behaviours. On the contrary, under the *response* approach, the richest quintile – which is the least represented group within farmers – adjusts less following the cereals price increase. For this reason, the difference between the *marginal* and *response* curves in Figure 3 is minimal in the fifth quintile's panel (up to less than 8 points), and the *response*-associated curve is less convex than for the other groups (that is the *response* components are relatively less important). Finally, for households belonging to the poorest quintile the required compensation under the *response* approach reaches its peak for price changes by around 80 per cent; the price variation corresponding to the highest loss increases with income (that is the peak is higher for richer households).

In Figure 5 we report the impact of cereals price changes on poverty estimates (headcount ratio and poverty gap [Foster, Greer, & Thorbecke, 1984]) obtained with the *marginal* and *response* methods.

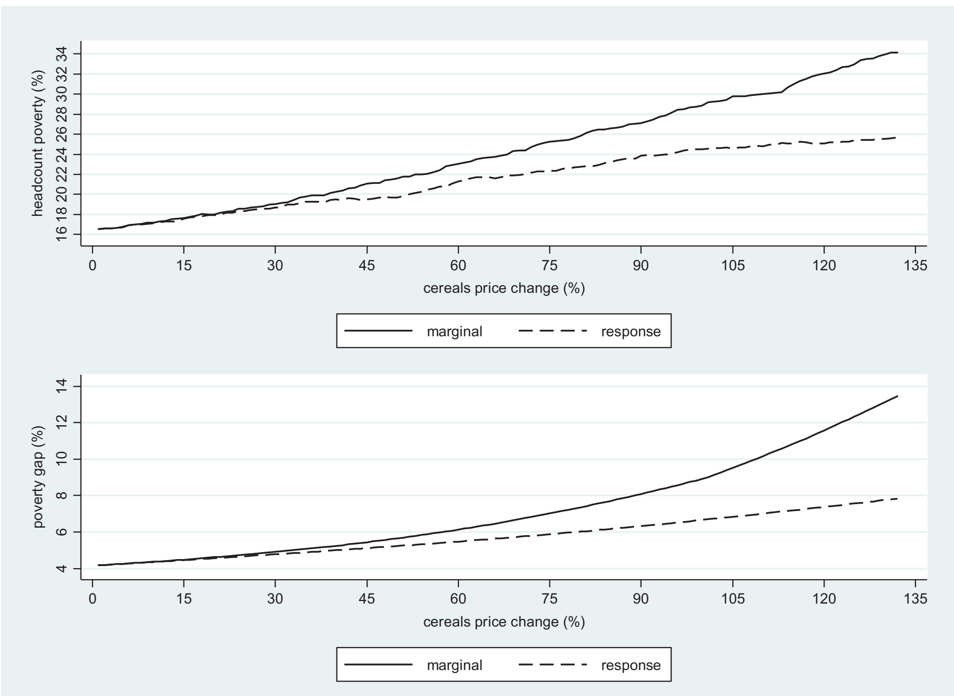

Figure 5. *Marginal* and *response* poverty estimates – headcount ratio and poverty gap.
Notes: For headcount poverty, poverty rates estimated with a *response* approach are statistically significantly lower at 5 per cent than those with the *marginal* approach starting for price increases above 12 per cent (with a few exceptions, that is 15, 19–23%); for the poverty gap, poverty rates under the *response* approach are always statistically significantly lower than those estimated with a *marginal* approach (that is for any price increase). Statistical tests have been performed through DASP (2007) – (Araar & Duclos, 2007).
Source: Authors' estimations using TNPS-1.

In line with our findings on required compensation, poverty effects differ substantially according to the theoretical approach we adopt, with the *response* method dominating (that is giving lower poverty rates) the *marginal* one along the entire range of price changes (with few exceptions for the headcount poverty indicator – see the note below Figure 5). As for the headcount ratio, the *marginal*-based estimations are higher than those obtained with a *response* approach up to 8 points (corresponding to a price increase by 132%), with the former finally doubling the initial poverty rate (16.7%). Except for a few values, the contribution to the poverty differences due to the second-order production effects become statistically significant only for price variations of 73 per cent and higher; the second-order consumption component statistically significantly contributes to reducing the incidence of poverty from a 28 per cent price change. The two combined second-order effects statistically affect poverty from 12 per cent increase. Moving to the poverty gap and consistent with the previously discussed finding (that is, the poorest are generally more able to adjust and to reduce the negative effects), the relative difference between the two approaches is even greater (6 points), with the *marginal*-based estimates jumping to up around 14 per cent (from an initial 4%). As stressed before, in this study we only focus on monetary welfare; the capacity of adjustments seems to significantly cushion the monetary effects but it may finally result in detrimental effects on non-monetary dimension (for example, nutrition, schooling, health).

In addition, while the growth (due to the change in the level of consumption) and redistribution (due to the change in the distribution of consumption) components both contribute to higher poverty rates when cereals price increases, the pattern of the growth and redistribution curves can differ according to the approach chosen (Figure 6). For the headcount poverty, while under the *marginal* framework the growth component drives the poverty changes along the whole range of price variation (contributing to up to two thirds of the total poverty change when the price change takes its highest value), under the

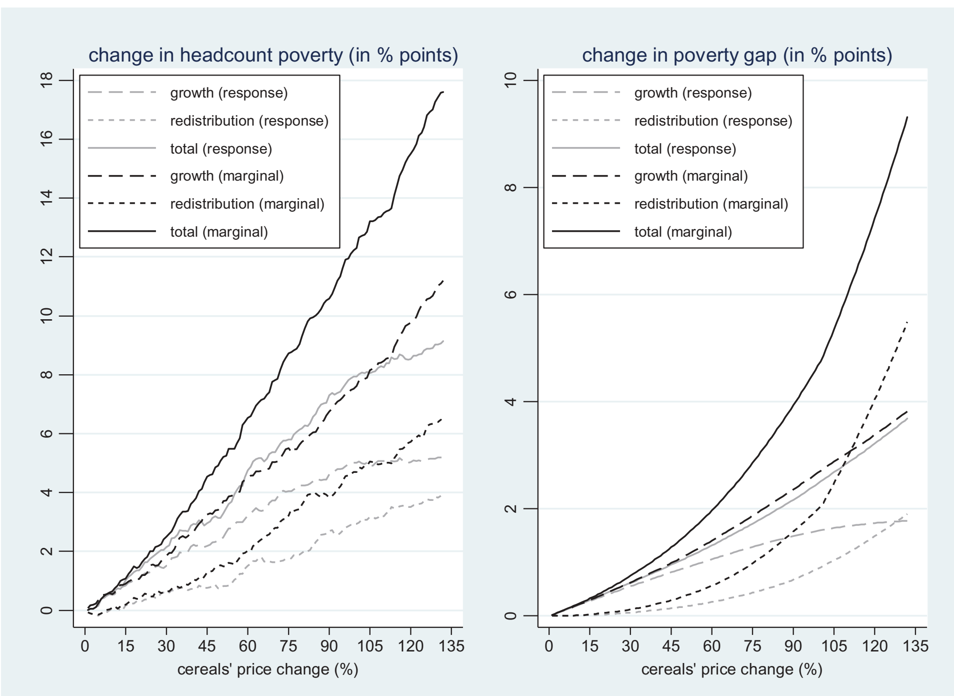

Figure 6. Decomposition of poverty changes by growth and redistribution components, *marginal* and *response* approaches.

Notes: Decomposition estimates through 'drdecomp' Stata command (Azevedo, Inchauste, Olivieri, Saavedra, & Winkler, 2013) which uses the Shapley/Shorrocks approach.

Source: Authors' estimations using TNPS-1.

response approach the growth component takes a concave shape and lies below the redistribution curve for price changes above 100 per cent. The concave shape of the growth component slows down the poverty effects under the *response* approach and contributes to the non-linear shape of the poverty curve. As for the poverty gap, the redistribution curve is convex in both the *marginal* and *response* estimates; this result reflects the larger emphasis put on extreme poverty in the poverty gap index. Also, the redistribution curve tends to cross (that is lying above) the growth curve – by then contributing the most to poverty gap changes – for large price variations. This is particularly the case simulated for the *marginal* approach. In the case of the *response* method, the growth component marginally decreases and contributes relatively less to the increase in the poverty gap.

Finally, some insightful results come from the poverty decomposition by income components (consumption and production, and first- and second-order) (see Figure 7). The sum of the first-order consumption and production effects corresponds to the poverty impact when a *marginal* approach is used, while when the second-order effects are added the poverty impact under the *response* framework is obtained. As expected, the first-order consumption effects are large and dominate all other (decreasing) effects, by contributing to an increase of the poverty incidence and gap by up around 20 and 9 percentage points (for price increase of 132%) respectively. The first-order production effects reduce poverty by 4 and 2 points respectively, and are larger than the indirect consumption effects for a price increase of around 100 per cent. The second-order consumption effects (which account for up around 5 and 3 percentage points in the reduction of poverty incidence and gap respectively) are indeed less important for relatively lower price increases, as households can take some time before adjusting their consumption behaviours and are probably more responsive for large price rise. The second-order production effects are relatively low and contribute to decreasing the poverty incidence and gap by just 1 and 0.1 percentage points respectively. This is possibly due to infrastructure, land and water constraints which characterised most sub-Saharan African contexts.

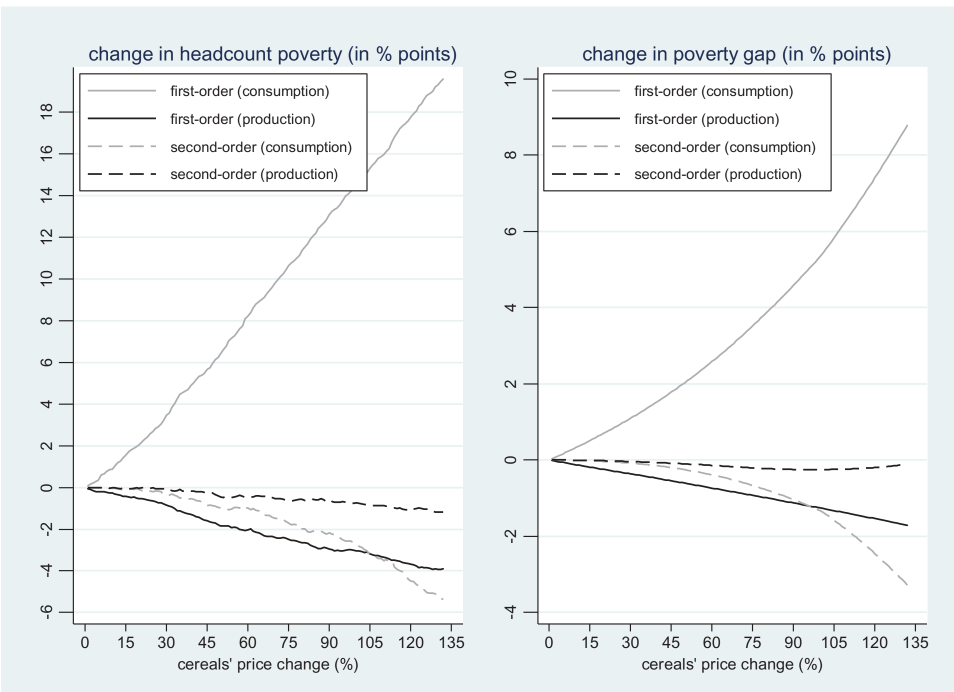

Figure 7. Decomposition of poverty changes by first and second-order effects, *marginal* and *response* approaches.

Notes: decomposition estimates through 'adecomp' Stata command (Azevedo et al., 2013) which uses the Shapley/Shorrocks approach.

Source: Authors' estimations using TNPS-1.

4. Conclusions

While most of the existing literature assessing the welfare impact of food price changes focuses on the *marginal* effects (that is without adjustments) on expenditure and production patterns, very few studies incorporate the adjustments in both the consumption and production behaviours by farm households, especially for the sub-Saharan African region. These second-order components seem particularly relevant under large food price changes, especially if they occur over the medium- to longer-term such as the 2006–2008 food crises.

By using data from Tanzania collected in 2008/2009, this work aimed to shed some light on the differences that may occur when a *marginal* approach (that is without any change in consumption and production) is used compared with a *response* model (that is with adjustments in both production and consumption decisions). For the *marginal* approach we used the framework proposed by Deaton in 1989; for the *response* approach, we estimated a non-separable agricultural household model, where joint adjustments in consumption, production and farmers' labour market behaviours are taken into account. Since, as in many poor rural-based developing countries, many households are both consumers and producers, such an approach seems particularly appropriate.

When consumption and production adjustments are allowed, households can adapt their consumption and production patterns by resulting in significantly lower deteriorations of their welfare, though significant differences emerge along the income distribution especially in urban areas. The average required compensation as estimated through the *marginal* approach for a cereal price increase at 132 per cent is 24 per cent, while when the *response* framework is used the compensation is just 8 per cent. The required compensation under the *marginal* method increases linearly with price rise, whereas the *response* approach predicts a concave shape relationship with the highest value at around a price rise by 100 per cent. The second-order (response) effects – in particular the consumption component – introduced in the *response* approach reduce the negative effects due to the first-order consumption effects more than proportionally with the price changes. Total *response* effects represent about up to 40 per cent of total first-order effects. As reflected by their different consumption and production patterns, some important differences emerge across quintiles, with the poorest one generally being the least affected irrespective of the methods we adopted whereas the most hit are the third one when the *marginal* approach is used and the richest group under the *response* framework. Finally, the predicted poverty changes differ substantially between the two approaches, with the *response* method stochastically dominating (that is giving lower poverty rates) the *marginal* one practically along the entire range of price changes irrespective of which poverty indicator is used. Some insightful differences also emerge about the driving components (growth versus redistribution) contributing to the pattern in the poverty changes. When the headcount poverty rate is used, in the *response* approach the growth component takes a concave shape in relation to the price increase, by progressively slowing down the negative effects on poverty and, for higher price changes, lying below the distribution growth. For the poverty gap, while the distribution curve contributes progressively more to poverty increase under both approaches for large price variations, under the *response* framework the growth component takes a concave shape with respect to the price change and contributes progressively less to the increase in the poverty gap. Finally, the first-order consumption effect dominates all other effects, and the second-order consumption component contributes to decreasing poverty more than the first-order production one for large price variations. Adjustments in production only modestly contribute to sizing down the negative effects due to a food price increase.

All in all, in the medium- to longer-term and under relatively large food price increases, the impact of food price change on household welfare and poverty risk to be seriously overestimated if a *marginal* approach is used. Understanding the implications of the two methods well can also be particularly relevant for policy interventions, which, as we well know, can differ depending on the time scales considered by the policy-maker.

Finally, while the primary objective of this article remains the discussion between different methods, we would like to stress that the relevance of the results presented above affects only the monetary dimension. We did not investigate the possible consequences on other dimensions of wellbeing. In particular, while the poorest quintile is simulated to be the less hit by cereals price change when the monetary dimension is used, we do not know the size and the distribution of the impacts when different measures are used, or whether specific intra-household dynamics take place due to the change in prices. For example, such variations may induce households to change their diet (for example without altering substantially the calorie intake but with a reduction in proteins or other macro or micro nutrients) or to change their intra-household allocations, which may affect some members (dis) proportionately more than others.

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Disclosure statement

No potential conflict of interest was reported by the authors.

Notes

1. See, for example, Swinnen and Squicciarini (2012) for a summary of the mixed potential effects of spikes of food prices on food security.
2. As long as a substitute is available in the local market, after a price rise in a given commodity, a consumer might divert immediately towards another good. For example, Ivanic and Martin (2014) make the hypotheses that consumption choices adjust immediately after the price change. On the production side, a household might indeed be constrained by – at least – biological production seasons (seeding and harvesting).
3. Note that the literature commonly uses the concept of *net benefit ratio* (*NBR*), which can be defined as the value of net sales (rather than net consumption as originally proposed by Deaton) as a proportion of household consumption.
4. In this study, the wage effects brought about by the consumer price increase is omitted since wage elasticity is likely to be negligible in a context like rural Tanzania (see Loening & Oseni, 2007). Indeed, Ivanic and Martin (2014) estimated the medium-run wage elasticity with respect to the price of maize (which is by and large the main cereal produced by Tanzanian farmers) to be equal to 0.1.
5. A detailed description of the theoretical framework and the estimation strategy is reported in Tiberti and Tiberti (2015). All models' parameters and variables are fully reported there as well.
6. See also Taylor and Adelman (2003) for a brief but exhaustive analytical description of AHMs.
7. As known, a separable AHM rests on the assumption that hired and family labour inputs are perfect substitutes and that the labour market works perfectly.
8. Non-proportional transaction costs refer to the cost that may change non-proportionally with the traded quantity. This implies non-proportional transaction costs for both (on-farm) labour demand and (off-farm) labour supply, and that both functions are nonlinear (see Henning & Henningsen, 2007b, for more discussion on that).
9. Nose and Yamauchi (2016) estimate long-term changes on production decisions brought about by the 2007/8 food crisis. To do that, the authors use panel data before and after the crisis (that is, from 2007 and 2010). With such data, the authors are able to capture long-term effects, for example, machine investments (fixed inputs) and the substitution effects between labour and capital, and the complementarities between land and capital investments.
10. These authors estimated the welfare effects as the difference of production and consumption effects. Here, we estimate the required compensation which is the difference of consumption and production effects.
11. Cereals prices data are from FAO/Global Information and Early Warning System on Food and Agriculture (GIEWS) online dataset http://www.fao.org/giews/pricetool/ (accessed in February 2015) (FAO, 2015). Given the lack of regional data, we use price changes referring to Dar es Salaam, although we are aware that this may overestimate the effect of price increases. However, the simulation exercise should mainly serve as illustration.
12. For reference, the peak (that is 132% in 2012) in real terms is around 95 per cent.
13. In this paper, with 'farm households' we mean those households engaged in cereal production only.
14. Data do not reflect accurately national patterns of near self-sufficiency in cereals, as revealed by FAOSTAT statistics. This is principally due to that fact that TNPS-1 survey is not representative of larger farmers (which are typically net sellers) and, as

a consequence, data may underestimate production levels. The survey sampling is based on the population frame, and large farmers are 'rare events', which cannot be sampled in a survey of about 3000 households. Overall, it is difficult to compare FAOSTAT statistics with aggregates from household surveys. Indeed, FAOSTAT statistics miss much of the informal cross-border trade.

15. 75 per cent is the cereal price increases occurred in the intermediate period between 2008 and 2012 (that is 2010).
16. This finding suggests a complementary relationship among the products, revealing that an increase in the product price leads new inputs to be drawn into general production. The use of additional inputs, in turn, increases the production of other products (for similar results, see, among others, Fulginiti & Perrin, 1990).
17. This mechanism could have some consequences on nutritional wellbeing. Indeed, diverting consumption towards less expensive commodities may imply that households change diet away from protein/micronutrient rich foods (see Minot, 1998).
18. While interesting, assessing how long the marginal and response effects can take go beyond the scope of this paper.
19. Similarly, D'Souza and Jolliffe (2014) find that the poorest are less affected (in caloric terms) than richer quantiles by food price rise.

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Appendix

As derived from the comparative statics (see Tiberti and Tiberti 2015 for a description of the full theoretical and empirical models), ψ_{p_v} can be written as:

$$\psi_{p_v} = \frac{-\varepsilon_{Lp_v} X_L + \Theta^H_{Lp_v} C_L + \eta_L \frac{p_v(X_v - C_v)}{Y} C_L}{\varepsilon_{LL} X_L + \varphi^h_L X^h_L - \varphi^s_L X^s_L - \Theta^H_{LL} C_L} \quad \text{(A1)}$$

with ε_{Lp_v} and ε_{LL} being the elasticity of labour input L with respect to the price of cereals v and with respect to the shadow wage respectively (estimated through the production function), $X_{L,v}$ the quantity of input L and output v respectively (from the production function), $\Theta^H_{Lp_v}$ and Θ^H_{LL} the Hicksian price elasticity of L with respect to the price of v and the shadow wage respectively (from the consumption function),$C_{L,v}$ the consumption of leisure L and v (from the consumption function), η_L the expenditure elasticity of leisure and Y the total expenditure (from the consumption function), φ^h_L and φ^s_L the price elasticity of hired (^{h}) and supplied (^{s}) labour respectively with respect to the shadow wage (from the labour choice function).

Table A1: Cereals price elasticities of the shadow wage, production netputs (outputs and inputs) and consumption commodities

	Elasticities with respect to the price of cereals	
	Farmers	Non-farmers
ψ(average)	-0.0369	
ψ(supply&hire)	-0.0338	
ψ(only supply)	-0.0345	
ψ(only hire)	-0.0390	
ψ(autarkic)	-0.0409	
$\varepsilon_{n=1}$	0.4399	
$\varepsilon_{n=2}$	1.4727***	
$\varepsilon_{n=3}$	1.6961*	
$\varepsilon_{n=4}$	1.7066***	
$\Theta_{i=1}$	-0.4587***	-0.4811***
$\Theta_{i=2}$	0.0424	0.5178***
$\Theta_{i=3}$	-0.1692***	0.1187*
$\Theta_{i=4}$	-0.1206*	-0.1499***
$\Theta_{i=5}$	-0.4842***	
$\eta_{i=1}$	0.8856***	0.8327***
$\eta_{i=2}$	0.7875***	0.7655***
$\eta_{i=3}$	1.1507***	1.1807***
$\eta_{i=4}$	0.9396***	1.1557***
$\eta_{i=5}$	2.1410***	

Notes: ψ= cereals price elasticity of the shadow wage; ε_n= average ns-AHS cereals price elasticity of production netput n as calculated in ; Θ_i= average ns-AHS cereals price elasticity of commodity i as calculated in for farmers, compensated cereals price elasticity of commodity i for non-farmers; η_i= income elasticity of commodity i (note that $\eta_i$enters in the estimation of ψ- not shown in the text)
Commodities (i): 1=maize and other cereals; 2=starches, pulses, dry nuts, seeds, vegetables, fruits, oil and fats; 3=sugar, sweets, meat, eggs, dairy, fish, salt, spices and beverages; 4=non-food; 5=leisure. Netputs (n): 1=cereals; 2=fertilizers & pesticides; 3=labour; 4=other crops.
***, **, * identify elasticities which are statistically different from 0 at 0.01, 0.05 and 0.10 level, respectively (the related Z-stats are calculated by bootstrapping with replacement after 1,000 replications).
Source: Estimates borrowed from Tiberti and Tiberti (2015)