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Rural Policies, Price Change and Poverty in Tanzania: an Agricultural Household Model-Based Assessment

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Abstract:
Exogenous shocks to farmers' consumption, production and labour market decisions are rarely considered accurately. For farm households, under labour market imperfections, such decisions are often interlinked. This calls for non-separable agricultural household models. According to this framework, second-order (or behavioural) effects include a direct (i.e., supply or demand reactions due to an exogenous shock) and an indirect (i.e., supply or demand adjustments to the endogenous variations in the shadow wage generated by the exogenous shock) component. Under large price changes or following structural interventions, such as those concerning land redistribution or mechanization practices, neglecting such second-order effects on consumption and production can bias the final impact on household welfare. The main objective of this study is thus to develop a robust and comprehensive tool to evaluate the effect on household welfare of different agricultural policies in Tanzania and food price changes. A two-stage estimation strategy is adopted: the shadow price of labour is first estimated and then used to estimate production and demand systems as well as labour market functions. These models are subsequently used to simulate the effect on household welfare of a hypothetical 40% increase in the price of cereals and other crops and a hypothetical 10% increase in the hectares of arable land and in the use of ox-ploughs. The results are finally compared with the case in which a separable model is adopted.

Keywords: Agricultural household models, poverty, agricultural policies, Tanzania

JEL Classification: D12, O12, O13, Q12, Q18

1. Introduction

The role of agriculture in economic development has been a central topic since the early stages of development thought. Nowadays, it is broadly acknowledged that agriculture changes its role according to the stages of development and that ignoring agricultural growth in early stages of development is generally bound to result in failure.

In addition, agriculture-based growth is generally more effective than non-agricultural-based growth in reducing poverty, as shown by Ravallion and Datt (1996), Christiaensen and Demery (2007) and Ligon and Sadoulet (2007). The assumption behind this is that agricultural growth favours lower income deciles proportionally more than higher deciles.

Moreover, many studies have shown that farm productivity improvements may also generate positive trickling-down effects on non-farm activities in rural areas (Hazell and Haggblade, 1991; Haggblade *et al*., 2007).[1] The policy implication is that agricultural development cannot be dismissed in any poverty alleviation strategy and this is particularly true in countries still dominated by a rural economy.

The Tanzanian economy is still dominated by agriculture, specifically small-scale farming,[2] and the bulk of the poor population lives in rural areas and earns most of its income from agriculture.[3] The aggregate agricultural output has grown sensibly since the end of the 1990s, though the average yields for most major crops have been declining (Lokina *et al.*, 2011) over the last years.[4] However, as recently discussed by Pauw and Thurlow (2010), the rapid growth of the agricultural sector between 2000 and 2007 was driven by large-scale farmers and concentrated among a few crops, thus resulting in an uneven pattern. It can thus be argued that the structure of agricultural growth, favouring large-scale producers of traditional export crops, as well as the poor

[1] As argued by Anriquez and Stamoulis (2007, pp. 16–17), agricultural growth may help poverty reduction through four main channels: directly, 'increasing the income and/or own consumption of small farmers', and indirectly, 'reducing food prices, […] increasing the income generated by the non-farm rural economy' (through the increase in the demand for the goods and services of the rural non-farm sector), and 'raising employment and wages of the unskilled' (agriculture typically being intensive in unskilled labour).

[2] The agricultural sector plays a pivotal role in the Tanzanian economy, accounting for over 45% of the GDP and employing nearly 75% of the labour force (World Bank, 2011).

[3] According to the most recent estimates (see GoT, 2011), about 80% of the poor live in rural areas and agriculture accounts for 75% of rural household incomes.

[4] For example, the cereal yields were just above 1.2 tons/ha from 2001 to 2007, below the peak of 1.5 tons/ha recorded in the 1990s (Cleaver *et al*., 2010).

performance of food crops explain the negligible impact of agricultural growth on poverty and nutrition.

The Tanzanian Government has recently recognized the pivotal role of agriculture in reducing poverty. Agricultural sector development is currently at a critical stage as new initiatives are being implemented. In particular, the Agricultural Sector Development Programme (ASDP), launched in 2006, is the operational programme that carries out the Agricultural Sector Development Strategy (ASDS) as well as broader frameworks, such as the National Strategy for Growth and Reduction of Poverty and the Tanzania Development Vision 2025, which endorse the Millennium Development Goals (see GoT, 2011).

Building on this evidence, the main objective of this study is to provide robust fundaments to anticipate how different positive and negative shocks potentially affect household welfare and poverty in rural areas.

With regard to the welfare impact due to price changes, most research takes into account only the direct effects of food price changes on both consumption and production (Ferreira *et al.*, 2013), which do not affect consumption and production behaviours at all. However, the behavioural effects concerning time allocation and consumption and production decisions are rarely considered accurately (if at all). In general, positive or negative shocks can indeed affect production by giving the farmer larger or smaller incentives to produce a given product with respect to another one, or they can affect the relative use of variable inputs. Similarly, the consumer is likely to adjust her consumption behaviour by, for example, diverting towards cheaper per calorie food. In a context of imperfect labour markets, which can call for non-separable agricultural household models in which consumption, production and labour market decisions are interlinked, these shocks can affect the endogenous shadow wage of labour and, therefore, the time allocation of family members. Second-order (or behavioural) effects can thus include a direct (i.e., the supply or demand reactions due to an exogenous shock) and an indirect (i.e., supply or demand adjustments to the endogenous variations in the shadow wage generated by the exogenous shock) component. As shown in this study, all this can have important empirical and policy implications. Under large price changes, neglecting the second-order effects in consumption and production decisions can bias the final impact on household welfare. Similarly, structural interventions, such as those concerning land or mechanization, can produce non-negligible behavioural effects on production and consumption decisions. This is why the approach that we propose in this study can be particularly appropriate for the kinds of phenomena analysed hereafter.

From the theoretical and empirical viewpoints, this research represents an additional contribution to the analysis of farmers' behaviour and welfare. As motivated previously, the context that we propose to study can be inscribed within the literature on non-separable agricultural household modelling (Singh *et al*., 1986; de Janvry *et al*., 1991).[5] Given the features of rural Tanzania (where labour is by far the most important input in farm production, accounting for about 70% of the total variable inputs, and the labour market is very thin), we consider the case of labour market imperfections due to transaction costs and labour heterogeneity. As for the model estimation, we build on the work by Henning and Henningsen (2007a), who adopted a two-stage estimation strategy: first, we estimate the shadow price of labour, then, in the second stage, we use this to estimate the production, consumption and labour market decisions. The parameters obtained from the different estimations are next used to calculate the consumption and production elasticities, into which the effect of exogenous changes on the shadow wage is plugged. These elasticities are subsequently used to simulate – in a partial equilibrium model – the welfare impact of a hypothetical 40% increase in the price of cereals and of other crops and a hypothetical 10% increase in the hectares of arable land and in the use of ox-ploughs. The results are finally compared with the case in which a separable model is adopted. The difference between the two approaches depends on the extent to which the shadow wage (and thus the time allocation of family members) adjusts following an exogenous shock. This is captured by the indirect component as described above. We find that the welfare effects due to an increase in the price of cereals under the separable and non-separable approaches do not differ significantly. Indeed, unimportant differences are found in the consumption component as farming households do not adjust significantly their shadow wage (and thus their time to leisure) following a change in the price of cereals. For the production component, under the non-separable approach the variation in the agricultural revenue does not differ significantly from the separable model as a faster growth in the production of cereals and other products is associated with a similarly faster demand for inputs. On the contrary, the welfare effects generated by the increase in the quasi-fixed inputs are

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[5] See Taylor and Adelman (2003) for a brief but exhaustive analytical description of agricultural household models.

larger (i.e., greater reduction in poverty rates) when a separable model is adopted as the size of the elasticity to the land size and the use of ox-ploughs are non-negligible (on average around 1.25 and 0.65 respectively). Such differences are mainly driven by the production side, with consumption contributing to reduce poverty under both approaches (though at a faster rate under the non-separable framework). In the non-separable approach, the negative price effect on profit through the endogenous change in the shadow wage more than compensates the positive effect on production directly generated by an increase in the quasi-fixed inputs. Differently, under the separable approach, a greater availability of land or a larger use of ox-ploughs are associated with an increase in the profits of farm households.

To the best of our knowledge, there are no studies in the sub-Saharan African region estimating the welfare effects of agricultural policies and food price changes through a full non-separable agricultural household model that takes into account the direct and indirect substitution effects in consumption and production decisions.

The paper is organized as follows. Section 2 presents the theoretical model and derives the comparative statics and elasticities for a non-separable agricultural household model. Section 3 discusses the estimation strategy and the empirical specification of the agricultural household model; the data and the estimations are presented in Section 4. In Section 5, the welfare and poverty effects of the increase in the price of cereals and the rise of quasi-fixed inputs (land and ox-ploughs) are simulated and discussed. Section 6 summarizes the main findings of the study and the policy implications.

2. Estimation of the Agricultural Household Model

2.2. Theoretical Model

In this section, we present a static model to estimate household production and consumption responses and labour market decisions when the labour market fails.[6] This is the case of the Tanzanian rural economy, which calls for a non-separable agricultural household modelling strategy. While the literature traditionally has not considered the interdependence between production, consumption and labour market

[6] We focus on labour market failures, because these are one of the major constraints in a context like that of rural Tanzania, where labour is the most important input in farm production (indeed, household labour is employed in 80.5% of cultivated plots (GoT, 2010)). Focusing only on labour market failures, we disregard other important constraints (above all, credit constraints, cf. Feder *et al*., 1990), as well as other aspects of farmers' decisions, such as price and production risk (Fafchamps, 1992), which are difficult to catch in a single-period analysis.

choices, non-separable agricultural household models (AHMs) explicitly take these links into account.

The farm household is assumed to maximize its utility subject to technology, budget and market constraints. Drawing on Henning and Henningsen (2007a), the utility function to be maximized can be represented as follows:

$$U(\boldsymbol{C}) \qquad (1)$$

where $\boldsymbol{C}$ represents a vector of consumption goods, including purchased commodities, own-consumed agricultural goods and leisure.

The constraints to the maximization problem are:

$$G(\boldsymbol{X}, \boldsymbol{R}) \qquad \text{(production function)} \qquad (2)$$

$$T_L - |X_L| + X_L^h - X_L^s - C_L \geq 0 \qquad \text{(time constraint)} \qquad (3)$$

$$\boldsymbol{P_c C} \leq \boldsymbol{P_X X} - g\left(X_L^h\right) + f\left(X_L^s\right) \qquad \text{(budget constraint)} \qquad (4)$$

Equation (2) formalizes the production technology, represented by a multi-input multi-output production function, where $\boldsymbol{X}$ is a vector of agricultural netputs (taking a positive value if outputs and a negative value if inputs) and $\boldsymbol{R}$ is a vector of quasi-fixed factors. Equation (3) expresses the time constraint faced by the farm household, where T_L identifies the total time available, $|X_L| = X_L^f + X_L^h$ is the total time of on-farm labour (distinguished between family labour (X_L^f) and hired labour (X_L^h)) and X_L^s is off-farm family labour. These variables capture time allocation and define four possible regimes of labour market participation: households that (1) simultaneously supply and hire labour; (2) only supply labour; (3) only hire labour; (4) neither supply nor hire labour, and only employ family labour (autarkic). According to the Tanzanian data, households that both supply and hire labour represent about 26% of the total farm households, while those that only supply labour, those that only hire and those that operate in an autarkic regime account for around 28, 19 and 27%. Finally, the budget constraint – equation (4) – simply says that the total household expenditure (estimated as the sum of all consumption goods $\boldsymbol{C}$ valued at prices $\boldsymbol{P_c}$) must not exceed the total monetary income identified by the total revenues from farming activities (obtained as the sum of all netputs $\boldsymbol{X}$ evaluated at prices $\boldsymbol{P_X}$) and incomes from off-farm labour – $f\left(X_L^s\right)$ – net of the cost of hired on-farm labour $g\left(X_L^h\right)$. As discussed by Henning and Henningsen (2007a), when labour market imperfections are due to non-proportional variable transaction costs (NTCs) or labour heterogeneity, $f(.)$ and $g(.)$ are non-linear in X_L^s and X_L^h, respectively, with $f(.)$ assumed to be concave and $g(.)$ convex. In such a case, the internal shadow wage is determined endogenously, production and consumption decisions are interlinked and the AHM becomes non-separable. Also, as demonstrated by Henning and Henningsen (2007a), when NTCs are assumed for off-farm supply of family labour as well as for hired on-farm labour, an endogenous shadow labour wage determines the time allocation even for farm households that supply off-farm labour or hire on-farm labour. Differently, when fixed or proportional transaction costs are assumed, a non-separable AHM results only if the transaction costs are sufficiently high, leading to a corner solution (i.e., the farm household neither supplies off-farm labour nor hires on-farm labour). The maximization problem identified in (1)–(4) is solved in two steps as fixed transaction costs generate discontinuities in $f(.)$ and $g(.)$. In such a situation, the idea proposed by Key *et al*. (2000) and Henning and Henningsen (2007a) is first to solve for the optimal solution given the labour market regime to which the household belongs, then to choose the regime leading to the highest utility.

2.3. Comparative Statics and Elasticities

In order to estimate the effects on household welfare due to a change to exogenous shocks, we need first to understand the impact that such shocks can have on household behaviours. The latter objective is usually achieved through comparative statics analysis, which helps in understanding the sign and, in empirical applications, the size of the impact on, for example, household consumption and production due to exogenous changes. As is usual in the AHM literature (de Janvry *et al*., 1991), the comparative statics of a non-separable AHM can be written as the sum of the direct component of the change in a given exogenous variable on household consumption and production and an indirect component representing the adjustments due to the change in the shadow wage generated by a change in the same variable. As the simulations performed in this study focus on changes in the price of commodity *i* or netput *n* and in quasi-fixed inputs *k*, we present hereafter the comparative statics for these two distinguished changes.

In the case of a change in the exogenous price of commodity/netput $v \in n,i$, the demand or supply reaction is:

$$\frac{dQ^{n,i}}{dp_v} = \underbrace{\left.\frac{dQ^{n,i}}{dp_v}\right|_{p_L^*}}_{\substack{direct\\component\\(sAHM)}} + \underbrace{\frac{dQ^{n,i}}{dp_L^*}\frac{dp_L^*}{dp_v}}_{\substack{indirect\\component\\(nsAHM)}} \tag{5}$$

By applying the implicit function theorem to the equation of time constraint(3), we find that the change in the shadow wage p_L^* following a variation in p_v is:

$$\frac{dp_L^*}{dp_v} = -\frac{\dfrac{\partial X_L}{\partial p_v} - \dfrac{\partial C_L}{\partial p_v}}{\dfrac{\partial X_L}{\partial p_L^*} + \dfrac{\partial X_L^h}{\partial p_L^*} - \dfrac{\partial X_L^s}{\partial p_L^*} - \dfrac{\partial C_L^H}{\partial p_L^*}} \tag{6}$$

with leisure/labour $L \in n,i$ and where the denominator captures the effect on time allocation due to the change in the shadow wage rate, while the numerator identifies the effect on time allocation following a change in the exogenous price. The component $\Lambda = \left(\partial X_L^h / \partial p_L^* - \partial X_L^s / \partial p_L^*\right)$ in the denominator indicates the degree of imperfection of the labour market due to NTCs. As shown by Henning and Henningsen (2007a), according to the first-order conditions on $f(.)$ and $g(.)$, we have that $\partial X_L^s / \partial p_L^* = \left(\partial^2 f / \partial X_L^{s2}\right)^{-1}$ and $\partial X_L^h / \partial p_L^* = \left(\partial^2 g / \partial X_L^{h2}\right)^{-1}$. As $f(.)$ and $g(.)$ are assumed to be concave and convex, respectively, Λ is always positive; when the labour market is missing (which is the case when the NTCs and labour heterogeneity are infinitely high), Λ is zero and approximates the case of an autarkic regime. In the opposite extreme case, that is, when the NTCs are zero and labour is perfectly homogenous, $f(.)$ and $g(.)$ become linear functions with Λ tending to infinity, the corresponding shadow wage variation is zero and equation (5) would approximate the case of a separable model, in which only the direct component is considered. From (6), the elasticity of the shadow wage with respect to p_v is:

$$\psi_{p_v} = \frac{dp_L^*}{dp_v}\frac{p_v}{p_L^*} = \frac{-\varepsilon_{Lp_v} X_L + \Theta_{Lp_v}^H C_L + \eta_L \left(\dfrac{\partial Y}{\partial p_v} - C_v\right)\dfrac{p_v}{Y} C_L}{\varepsilon_{LL} X_L + \varphi_L^h X_L^h - \varphi_L^s X_L^s - \Theta_{LL}^H C_L} \tag{7}$$

where Y identifies the total household consumption. For *v*=cereals or other crops, which is the focus of our simulation and which farm households can both consume and produce, and evaluating $\dfrac{\partial Y}{\partial p_v}$, (7) can be rewritten as:

$$\psi_{p_v}\Big|_{v=cereals/other\_crops} = \frac{-\varepsilon_{Lp_v} X_L + \Theta^H_{Lp_v} C_L + \eta_L \frac{p_v\left(X_v - C_v\right)}{Y} C_L}{\varepsilon_{LL} X_L + \varphi^h_L X^h_L - \varphi^s_L X^s_L - \Theta^H_{LL} C_L} \qquad (8)$$

where ε_{Lp_v} is the price elasticity of the labour input with respect to the price of netput *v* (production function); $\Theta^H_{Lp_v}$ is the Hicksian price elasticity of leisure with respect to the price of good *v* (consumption function); η_L is the income elasticity of leisure (consumption function); ε_{LL} is the own-price elasticity of labour (production function); φ^h_L is the price elasticity of hired labour with respect to the (shadow) price of labour (labour choice function); φ^s_L is the price elasticity of supplied labour with respect to the (shadow) price of labour (labour choice function); and Θ^H_{LL} is the Hicksian own price elasticity of leisure (consumption function).

From (5), we derive the price elasticities with respect to the price of *v* under a non-separable AHM model for outputs/inputs (production side) and for commodities (consumption side):

Production (with *v*=cereals or other crops): $\varepsilon^{nsAHM}_{nv} = \varepsilon^{sAHM}_{nv} + \varepsilon_{nL}\psi_{p_v}$ (9)

where ε^{sAHM}_{nv} is the price elasticity of the separable model and ε_{nL} is the price elasticity of output/input *n* with respect to the price of labour:

Consumption (with *v*=cereals or other crops):

$$\Theta^{nsAHM}_{iv} = \Theta^{sAHM}_{iv} + \Theta^H_{iL}\psi_{p_v}$$
$$= \Theta^H_{iv} + \eta_i \frac{p_v\left(X_v - C_v\right)}{Y} + \Theta^H_{iL}\psi_{p_v} \qquad (10)$$

where Θ^{sAHM}_{iv} is the price elasticity of commodity *i* with respect to commodity *v* under the separable model (and corresponds to the usual Marshallian price elasticity) and Θ^H_{iv} and Θ^H_{iL} are the Hicksian price elasticities with respect to *v* and leisure, respectively.

Now, let us consider a change in a quasi-fix input z_k. As in the previous case, the comparative statics of a non-separable AHM is:

$$\frac{dQ^{n,i}}{dz_k} = \underbrace{\left.\frac{dQ^{n,i}}{dz_k}\right|_{p_L^*}}_{\substack{direct \\ component \\ (sFHM)}} + \underbrace{\frac{dQ^{n,i}}{dp_L^*}\frac{dp_L^*}{dz_k}}_{\substack{indirect \\ component \\ (nsFHM)}} \qquad (11)$$

and the shadow price adjustment can be written as:

$$\frac{dp_L^*}{dz_k} = -\frac{\dfrac{\partial X_L}{\partial z_k} - \dfrac{\partial C_L}{\partial Y}\dfrac{\partial Y}{\partial z_k}}{\dfrac{\partial X_L}{\partial p_L^*} + \dfrac{\partial X_L^h}{\partial p_L^*} - \dfrac{\partial X_L^s}{\partial p_L^*} - \dfrac{\partial C_L^H}{\partial p_L^*}} \qquad (12)$$

where $\frac{\partial C_L}{\partial Y}\frac{\partial Y}{\partial z_k}$ is the policy-induced income effect on the demand for leisure. The elasticity of the shadow wage with respect to quasi-fix input z_k can be written as:

$$\psi_{z_k} = \frac{dp_L^*}{dz_k}\frac{z_k}{p_L^*} = \frac{-\varepsilon_{Lz_k} X_L + \eta_L \varepsilon_{\pi z_k} C_L}{\varepsilon_{LL} X_L + \varphi_L^h X_L^h - \varphi_L^s X_L^s - \Theta_{LL}^H C_L} \qquad (13)$$

where $\varepsilon_{\pi z_k}$ is the profit elasticity with respect to z_k. Similarly to the case of a change in prices, we derive the elasticities with respect to z_k under a non-separable farm household model for outputs/inputs (production side) and for commodities (consumption side):

Production: $\varepsilon_{nz_k}^{nsAHM} = \varepsilon_{nz_k}^{sAHM} + \varepsilon_{nL}\psi_{z_k}$ (14)

Consumption: $\Theta_{iz_k}^{nsAHM} = \eta_i \varepsilon_{\pi z_k} + \Theta_{iL}^H \psi_{z_k}$ (15)

with the elasticity of commodity *i* with respect to input z_k ($\Theta_{iz_k}^{nsAHM}$) being influenced by the income effect ($\eta_i \varepsilon_{\pi z_k}$) and the indirect component $\Theta_{iL}^H \psi_{z_k}$.

3. Estimation Strategy

Starting from the empirical approach proposed by Henning and Henningsen (2007a and 2007b), we estimate a non-separable agricultural household model using the 2008/2009 Tanzania National Panel Survey Integrated Households Survey (TNPS-1) data (see GoT, 2010). This model is then used to assess the impact on household welfare of different agricultural policies and price changes.

A two-stage estimation strategy is adopted, estimating first the shadow prices of family labour through production function modelling. The shadow wage rate is then included in a multi-input multi-output production system, a complete demand system and labour cost and income functions to estimate production, consumption and labour market decisions. In addition, for both labour input (which enters the production system) and its counterpart (leisure, which enters the consumption system), the price corresponds to the household shadow wage as estimated in the first stage.

The shadow wage of household labour is estimated by following the procedure proposed by Jacoby (1993). The Cobb–Douglas functional form is used, despite its limitations, because of the easiness of its estimation and interpretation (see Abdulai and Regmi, 2000).

To assess the interactions among different farm products resulting from the implementation of alternative agricultural and price policies, we estimate the output supply and input demand as well as the profit elasticities. This is carried out by estimating a system of equations derived from a restricted profit-maximization specification. The production technology is represented by a *translog* multi-input multi-output profit function, following quite a common methodology proposed, among others, by Fulginiti and Perrin (1990).

On the consumption side, the AID System proposed by Deaton and Muellbauer (1980) is used to estimate the impact of changes in prices and income on household consumption behaviour. Finally, labour market decisions are estimated through an extended Heckman approach.

3.1 Empirical Specification

As noted before, the econometric estimation of the model requires a two-stage estimation strategy, since the shadow wage cannot be observed directly (Henning and Henningsen, 2007a and 2007b). Thus, in the first stage, we estimate the shadow prices of family labour for adult males and females; and in the second stage we estimate the production system (profit and netput share functions), the consumption demand system and the wage functions. This approach also allows us to overcome fairly robustly the complexity of simultaneous estimation of the consumption and production functions under labour market failure.

3.1.1 The Shadow Wage

The Cobb–Douglas production function is specified as follows (Jacoby, 1993; Abdulai and Regmi, 2000):

$$\ln O = \sum_{j=1}^{n} \alpha_j \ln Z_j + \sum_{k=1}^{m} \gamma_k d_k + \varepsilon \tag{16}$$

where O represents the total value of the agricultural output produced by the farm household, Z_j identifies the quantity of input j used by the farmer and d_k is a vector of location dummies. The inputs represented by vector Z_j are the total land area, quantity of pesticides, quantity of inorganic fertilizers, quantity of organic fertilizers, days of hired male labour, days of hired female labour, days of family adult male labour, days of family adult female labour, value of mechanization, an index for irrigated plots[7] and an index of land quality[8]. In addition, the age, sex and level of education of the household head are included as proxies for the management input. Finally, the distance of plots from principal roads and markets is included.[9]

Since input variables are expected to be endogenous regressors, instrumental variables (IVs) are used to estimate the Cobb–Douglas production function.

Once (16) has been estimated, the shadow daily wage rates associated with family male and female labour are derived as follows:

$$p^*_{L,g} = \frac{\hat{\alpha}_{L,g}\hat{O}}{L_g}, \text{ g = 1, 2} \tag{17}$$

where $\hat{O}$ is the predicted value of output and $\hat{\alpha}_{L,g}$ is the estimated coefficient associated with the total days of on-farm family labour by adult males and females (L_1 and L_2), respectively. A weighted unique household shadow wage p^*_L is then calculated, in which the weights are estimated as the share of the days of males and females in the total days of household adult members for on-farm activities during the long-rainy season.

3.1.2 Farm Production System

Following the empirical procedure proposed by Sidhu and Baanante (1981), a *translog* profit function is estimated in order to obtain the full coefficients of the profit function as well as the input and output elasticities with respect to the prices and quasi-fixed inputs.

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[7] The index for plot irrigation is the mean (weighted by plot size) of irrigated plots by households.

[8] The questionnaire reports a value according to the soil quality of the plot ('bad', 'average' and 'good'). The index of land quality is the mean (weighted by plot size) of these values by households.

[9] In the regression, all the variable inputs are in logarithmic form. Given the presence of zero values in all the inputs, except land, we add one to all the inputs' value and then transform them into logarithms.

The profit function is written as

$$\ln \pi = a_0 + \sum_n a_n \ln p_n + \sum_k b_k \ln z_k + \frac{1}{2}\sum_{n,r} b_{nr} \ln p_n \ln p_r + \\ + \frac{1}{2}\sum_{k,m} c_{km} \ln z_k \ln z_m + \sum_{n,k} d_{nk} \ln p_n \ln z_k + \varepsilon \qquad (18)$$

Subject to the usual constraints:

$$b_{nr} = b_{rn} \; ; \; c_{km} = c_{mk} \; ; \; \sum_n a_n = 1 \; ; \; \sum_k b_k = 1 \; ; \; \sum_{nr} b_{nr} = \sum_k c_{km} = \sum_n d_{nk} = 0$$

where π is the household profit, p_n is the median price of output or input *n* estimated at the cluster level,[10] except for the (shadow) price of labour, which is estimated at the household level, z_k is the quasi-fixed input *k* used by the household and ε is the household residual term. In order to take them into consideration, it is necessary to run the system's estimation on households with non-negative profit only (or those of which the sum of profit shares is not lower than zero). The non-negativity of profit is necessary since $\ln \pi$ is not defined for negative values of profit; in addition, non-negativity is a condition that ensures the existence of the duality relationship between production and profit functions (Chaudhary *et al.*, 1998).[11] As in Henning and Henningsen (2007a), the shadow price of labour entering the production system is affected by other netputs' price, as well as by land and capital endowments.

In order to obtain the netputs' shares, the first step is to associate every crop cultivated in the 2008 long-rainy[12] season[13] (*masika*) with a specific category of goods. All the crops cultivated in the 2008 long-rainy season are grouped into two categories: cereals

[10] To take into account the geographical differences in prices, we construct clusters as a combination of regions, urban–rural location and districts, which results in 173 clusters. To give an example, cluster 1 derives from the combination of district 1, region 1 and urban areas; cluster 2 from the combination of district 2, region 1 and urban areas; and so on.

[11] As discussed in Bos and Koetter (2011), although including only households with non-negative profits is a dominant solution to such a case, it can have two shortcomings: first, we cannot derive efficiency scores for farm with negative profits; second, not adjusting for truncation may generate biased results. However, we cannot know *a priori* the direction of such bias. In an attempt to validate our results, we tested the difference of the mean for each of the explanatory variables entering the production system between the full sample and profit-making farms only. None of these differences are statistically different from zero (even at 10%). Also, though not with absolute certainty, we can conclude that the value of the elasticities on the production side is not likely to be biased through the variables' averages (that enter the elasticities' estimation – see (21) and (22) – together with the estimated functional parameters, for which, on the contrary, we cannot say anything with respect to their potential biases).

[12] It should be noted that quite a severe drought occurred during the 2008/2009 season, particularly in the northern part of Tanzania (Chang'a, 2009).

[13] The reference period for farm production is the 2008 long-rainy season, both for crops cultivated and for input used. Data regarding the short-rainy season (*vuli*) are not included in the empirical analysis since too few households cultivate during this season. Its exclusion is thus not expected to change the whole results significantly.

(including maize, which accounts for 60% of the value of this category, rice, sorghum, millet and wheat) and other crops (including tubers and roots, legumes, oil, fruits, vegetables and cash crops). ‘Fertilizers (organic and inorganic) and pesticides’ and ‘on-farm family labour and hired on-farm labour’ are the two categories identifying the variable inputs. All farm households in our sample use the labour input, while around 68% use fertilizers and pesticides.

With respect to quasi-fixed inputs, z_k includes the use of improved seeds, land, irrigation and ownership of an ox-plough.

First-order differentiation of (18) results in a system of share equations s_n:

$$s_n = \frac{\partial \ln \pi}{\partial \ln p_n} = \frac{p_n Y_n}{\pi} \qquad (19)$$

which are linear in normalized prices:

$$s_n = a_n + \sum_r b_{nr} \ln p_r + \sum_k c_{nk} \ln z_k + \upsilon_n \qquad (20)$$

Since the input and output shares sum to unity, one input or output equation is dropped from the system to avoid singularity problems. Thus, the production system consists of one output category (cereals, s_1) and two input categories (fertilizers and pesticides, and labour, s_2 and s_3, respectively).

The dropped profit share equation is that of other crops, the coefficients of which are obtained using the adding-up property. The various symmetry and homogeneity constraints are imposed during the estimation.

Profit and profit share functions are estimated simultaneously, by imposing equality between the coefficients in the share equation (20) and those in the profit equation (18). The simultaneous estimation allows us to satisfy, among other things, the assumption of profit maximization.

As suggested by Sidhu and Baanante (1981), the system of profit and profit shares equations is estimated through the iterated seemingly unrelated regression (*SUR*) approach.

From (20), the output supply and input demand elasticities to the own and cross prices are calculated as

$$\varepsilon_{nn} = \frac{b_{nn}}{s_n} + s_n - 1 \qquad \text{and} \qquad \varepsilon_{nr} = \frac{b_{nr}}{s_n} + s_r \qquad (21)$$

while the elasticity of profit with respect to the netputs' prices ($\varepsilon_{\pi n}$) is simply a_n as in (18). Finally, the netput *n* elasticity with respect to z_k is:

$$\varepsilon_{nz_k} = \sum_n c_{nk} \ln P_n + b_k + \frac{c_{nk}}{s_n} \qquad (22)$$

while the elasticity of profit with respect to quasi-fixed inputs ($\varepsilon_{\pi z_k}$) is simply b_k as in (18).

3.1.3 Household Consumption Decisions

On the consumption side, the Almost Ideal Demand System (AID System) proposed by Deaton and Muellbauer (1980) is used to estimate the impact of changes in prices and income on household consumption behaviour.

The AID System-associated demand functions are derived as the budget share as follows:

$$w_i = a_i + \sum_j b_{ij} \ln p_j + c_i \ln\left(\frac{x}{d(p)}\right) + \varepsilon_i \qquad (23)$$

constrained to:

$$\sum_i a_i = 1 \; ; \; \sum_j b_{ij} = 0 \; ; \; \sum_i c_i = 0 \; ; \; b_{ij} = b_{ji}$$

and where

$$\ln d(p) = a_0 + \sum_i a_i \ln p_i + \frac{1}{2} \sum_i \sum_j b_{ij} \ln p_i \ln p_j \qquad (24)$$

where w_i is the household budget share associated with category *i* and p_j is the cluster-weighted median price of category *j*, x is the per-adult equivalent household's total expenditure, a_0 is a parameter that is assumed to be slightly less (i.e., 0.95) than the lowest value of $\ln x$ observed in the data set (as normally performed in the literature) and ε_i is the residual term.

We group household expenditure into five categories of goods, i.e., three food categories, leisure[14] and a non-food category. The food categories are: maize and

[14] The amount of leisure is determined by calculating the yearly available time of households minus the time spent on labour activities. Consistently with the on-farm family input of the production function, we only estimate the amount of leisure for adult members aged between 15 and 60 years old. It is assumed that each household member aged between 15 years and 60 years has 10 hours per day. The annual available time of the household is calculated by multiplying the total hours per day of all the household adult members by 365. The time spent on labour activities comprises on-farm labour, other

other cereals; starches, pulses, dry nuts, seeds, vegetables, fruits, oil and fats; and sugar, sweets, meat, eggs, dairy, fish, salt, spices and beverages.[15] Deliberately, the first two food categories broadly correspond to the cereals and other crops categories in the production function (see above).

The AID System is then estimated as specified by equation (23), in which budget shares are linear in b_{ij}. Since prices are estimated at the cluster level, the spatial variability of prices in Tanzania is taken into account. As for the price of non-food commodities, the Fisher price index for non-food items is used[16] because of the large heterogeneity in the units of measure of the different non-food commodities included in this category. As discussed above, the (shadow) price of leisure is estimated at the household level.

As in Henning and Henningsen (2007a), the shadow price of leisure entering the consumption system is affected by socio-demographic factors proxied by the size of the household, the number of children in the household and the literacy level, as well as by the price of other commodities.

The adding-up property of the demand system requires one of the expenditure share equations to be dropped from the system to avoid singularity problems. The dropped expenditure share equation is non-food, the coefficients of which are obtained using the adding-up property. Symmetry and the various homogeneity constraints are imposed in the estimation of the system of equations.

The uncompensated (or Marshallian) own and cross-price elasticities (Θ_{ii} and Θ_{ij}) and the income elasticity (η_i) of the i-th good are:

$$\Theta_{ii} = \left(\frac{b_{ii}}{w_i}\right) - c_i - 1\,;\ \Theta_{ij} = \frac{b_{ij}}{w_i} - \frac{c_i}{w_i} w_j\,;\ \eta_i = \frac{c_i}{w_i} + 1 \qquad (25)$$

3.1.4 Labour Market Decisions

A quadratic shape for the labour income $f(.)$ and labour cost $g(.)$ functions is adopted to allow imperfect labour markets due to non-proportional, fixed and

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self-employment jobs, wage jobs and unpaid family activities. To estimate the value of leisure, the hourly shadow wage rate in agricultural activities is multiplied by the hours of leisure per day.

[15] The total consumption values in the household survey are converted to an annual basis when required. In addition, individual consumption per adult equivalent is calculated using the 'caloric requirements' approach to determine equivalence scales, with data from the FAO/WHO/UNU (1985).

[16] The Fisher price index for non-food commodities is obtained from a personal communication with the World Bank, as no official documents on this have been published yet.

proportional transaction costs (NTCs, FTCs and PTCs, respectively). Following Henning and Henningsen (2007a), we know that when $f(.)$ and $g(.)$ are assumed to be quadratic, the corresponding shadow wage functions are linear:

$$P_L^* = \beta_0^s + \beta_1^s X_L^s + \beta^s z^s \tag{26}$$

$$P_L^* = \beta_0^h + \beta_1^h X_L^h + \beta^h z^h \tag{27}$$

with z^s and z^h identifying – among others – the factors that can influence the PTCs and NTCs of supplying and hiring labour, the average skills of supplied off-farm and hired on-farm labour and the average wage at the cluster level. After the labour shadow price in (17) has been predicted, (26) and (27) are estimated. In order to circumvent possible endogeneity issues, X_L^s and X_L^h are first estimated and their predicted values are then inserted into (26) and (27), respectively. In the first stage, a switching regression model is used to estimate the labour supply and demand equations for each of the (four) possible labour market regimes. To overcome possible sample selection bias, before estimating the first stage, the market participation equations are estimated through a bivariate probit model; from this model, the conditional expectation of the error terms is obtained and then plugged into the first and second stages of the shadow wage equations. For full details of the estimation procedures followed in this section, see Henning and Henningsen (2007b).

3.2 Welfare and Poverty Effects

Similarly to Robles and Torero (2010), the variation in household welfare due to a change in the price of netput or commodity v (dB^p) is given by:

$$dB^{p_v} = \left[s_v y \frac{dp_v}{p_v} - w_v y \frac{dp_v}{p_v} \right] + \frac{1}{2} \left[\sum_n s_n \varepsilon_{\mathbf{nv}}^{\boldsymbol{nsAHM}} y \left(\frac{dp_v}{p_v} \right)^2 - \sum_i w_i \boldsymbol{\Theta}_{\mathbf{iv}}^{\boldsymbol{nsAHM}} y \left(\frac{dp_v}{p_v} \right)^2 \right] \tag{28}$$

To estimate the change in welfare following a variation in a fixed input (z), we calculate the differential of household welfare $B\left(y(z_k), \pi(z_k)\right)$ with respect to z_k:

$$dB^z = \sum_n s_n \varepsilon_{\mathbf{nz_k}}^{\boldsymbol{nsAHM}} y \frac{dz_k}{z_k} + \sum_i w_i \boldsymbol{\Theta}_{\mathbf{iz_k}}^{\boldsymbol{nsAHM}} y \frac{dz_k}{z_k} \tag{29}$$

where $\frac{dp_v}{p_v}$ and $\frac{dz_k}{z_k}$ are the percentage change in price and fixed input, respectively, and y is the total household consumption. While all the households in the sample are potentially affected by the price change, only farmers are affected by the change in fixed inputs.

Poverty analysis is finally carried out to estimate the impact on household welfare due to agricultural policies and prices changes, which affect both production and consumption behaviours.

The standard Foster–Greer–Thorbecke (1984) (FGT) measures of monetary poverty (headcount ratio and poverty gap) are calculated for the base scenario (i.e., the scenario without simulations) and for each simulation scenario. Absolute changes in the household income are fully transmitted to the household consumption with the hypothesis that the marginal rate of savings is zero. A monthly poverty line of 18007 Tanzanian shillings and a Fisher price index (to take spatial and temporal differences into account) as estimated by the World Bank is used[17].

4. Data and Estimation Results[18]

4.1 Data

This study uses data from the 2008/2009 Year One National Panel Survey Integrated Households Survey (TNPS-1), implemented by the Tanzania National Bureau of Statistics (GoT, 2010) between October 2008 to September 2009. As the scope of this study is to propose a comprehensive tool to assess *ex ante* the potential effect of exogenous shocks on the welfare of agricultural households, we did not use the other waves of the survey. The survey collected information from a nationally representative sample of 3,265 households (2,063 households in rural areas and 1,202 in urban areas). The questionnaire covers the socio-economic characteristics of the household regarding demographics, education, health, agriculture, labour force and employment, income, expenditure, assets, anthropometric data, security and safety, social safety nets, credit, subjective assessment of well-being, recent shocks and prices of food and non-food items. The Agricultural Questionnaire collects information on agricultural activities at both the plot and the crop level on inputs, outputs and sales. The survey also contains information on community-wide characteristics, including the availability of services, physical and economic infrastructure, and changes that might have affected the communities over the last five

[17] The information about the poverty line and the price index are obtained from a personal communication with the World Bank, as no official documents on these have been published yet.

[18] Table 10 provides the definitions, means and standard deviations of all the variables used in the main empirical specifications.

years (GoT, 2010). As the focus of this study is on agricultural households, most of the empirical analysis is performed on households that reported positive agricultural production in the 2008/2009 long-rainy season. This subsample includes 1,931 households, of which around 90% live in rural areas and about 10% in urban areas. It is not surprising that a tenth of agricultural households were surveyed in urban areas, considering the important role played by urban agriculture in many developing countries (for more details on this see, e.g., Zezza and Tasciotti, 2010). As discussed below, we use the full sample (farmers and non-farmers) only to compare the consumption behaviour and the poverty effects due to a food price increase between farmers and non-farmers.

4.2 The Shadow Wage

The robust OLS and IV estimates of the Cobb–Douglas production function are reported in Table 1. The sample used for these estimations consists of 1860 households (out of 1,931 agricultural households – 71 households are dropped as they show a missing value for agricultural production). All these households have at least one adult male or female working on the family farm; 92% with at least one adult female and around 82% with at least one adult male. Most of the OLS and IV estimated coefficients have the expected signs. In the OLS estimates all the labour typologies have impacts significantly different from zero, while this is not the case for hired labour in the IV regression. Land quality and mechanization have a significantly positive effect on farm production. The household head’s schooling does not have a significant impact on the agricultural output, failing to support the widely accepted role of human capital in improving farmers’ production. Furthermore, the household head’s age is not significant. Infrastructures such as roads and markets have no statistically significant effects on production.

However, the physical inputs are likely to be endogenous and, as discussed in Abdullai and Regmi (2000), assuming that inputs are exogenous would contradict the implications of the agricultural household model. Therefore, instrumental variables (IVs) are included to estimate the production function. We use the same set of instruments as Jacoby (1993), namely: the number of children (aged < 15), number of elderly people (aged > 60), number of female adults (aged > 14 and < 61), number of male adults (aged > 14 and < 61); price of cereals (logarithm) and adult farm daily wage; home ownership dummy (1 if own, 0 otherwise), cooking fuel dummy (1 if electricity or gas, 0 otherwise) and source of drinking water dummy (1 if piped water inside or outside dwelling, 0 otherwise). The endogeneity is confirmed by both Wooldridge's robust score and robust regression-based tests. Moreover, Wooldridge's robust score test, checking the validity of instrumental variables (i.e., uncorrelated with the error term), confirms that the instruments are valid. The coefficients from the IV estimate are used to estimate the household shadow wage.[19] As in Jacoby (1993) and Abdullai and Regmi (2000), we find that IV estimates are poorer than those obtained with OLS (see the values of R2), with most physical input coefficients becoming statistically insignificant when the IV model is used. However, most importantly for the purpose of our study, the estimated coefficients associated with female and male on-farm family labour are statistically significant in both approaches and their values do not differ substantially between the OLS and IV estimates.

[INSERT TABLE 1]

4.3 Production

For the reasons discussed above, only households with non-negative profits are used to estimate the production system. This means that the sample finally used for this estimation contains 1,589 observations. The coefficients[20] of the output shares, estimated through a *translog* production system ((20)), as well as the profit function ((18)), are reported in Table 2. The profit share functions refer to (1) cereals, (2) fertilizers and pesticides and (3) labour (on-farm family and hired), while the other crops category share (4) is estimated by difference (all these shares sum to one). Furthermore, four quasi-fixed inputs (z) are included in the system: z_1 is the probability of using improved seeds; z_2 is the land input measured as hectares cultivated by farms in the long-rainy season 2008/2009; z_3 is the probability of using an ox-plough; and z_4 is the probability of owning irrigated plots. For estimation requirements and simulation purposes, we estimate z_1, z_3 and z_4 through separate probit models in such a way that (i.e., by adding the estimated generalized residuals) the average predicted probability corresponds exactly to the average of its associated (observed) binary variable. Four agro-zone dummy variables are added to the

[19] These are the statistical tests available in Stata when 2sls with the robust standard errors option is run.

[20] Although we are aware of the presence of different farming systems in Tanzania, this analysis is conducted ignoring such differences, since a detailed analysis of different farming systems is beyond the scope of this study.

specification to control for fixed geographic effects, such as soil quality, climate and rain precipitation.

[INSERT TABLE 2]

The coefficients in Table 2 are then used to estimate the price and quasi-fixed input elasticities.

The full set of price and quasi-fixed input elasticities for the output supply and input demand are computed using the sample means, according to equations (21) and (22) (Table 3). Both the supply of cereals and the supply of other crops are inelastic to their own price (below 1), with the elasticity of cereals not statistically significant. This result is clearly affected by the relevance in the profit share of maize and other crops (such as tubers), which are mainly grown for self-consumption purposes. This is also an indication of the poor diversification in food consumption preferences for farmers. In other words, an increase in a crop's price does not induce the farmer to produce more of that item to sell it in the market by substituting its consumption with something else. The availability of other food products is indeed limited, especially in the rural context.

The supply cross-price elasticities are positive, revealing a complementary relationship among the commodities, a result in line with the findings of Ball (1988), Fulginiti and Perrin (1990) and Colby *et al*. (2000). This implies that an increase in the commodity price leads new inputs to be drawn into general production, leading, in turn, to an increase in the production of other products.

The result that the supply cross-price elasticities are larger than the own-price elasticities suggests that production is likely to be driven by consumption decisions. When one crop's price increases, farmers are diverted to consume less of that crop. They are likely to be induced to produce substantially more of another crop in order to compensate for the lower consumption of the first product. This mechanism may be particularly true for farmers engaged in the production of only one crop (or one category of crops). In this regard and based on the sample used for these estimates, we found that slightly less than half a percent of farming households produce either cereals or other crops.

All the cross-price elasticities for inputs are negative, which means that the inputs are complements: an increase in one input price, holding other categories' prices constant, decreases the demand for other inputs. Similar results were reported by Fulginiti and Perrin (1990). The negative cross-price elasticity of inputs' demand with respect to the shadow wage and to the price of other variable inputs shows that the combined use of labour and other inputs increases agricultural production synergistically. Indeed, a decrease in any of these two variable inputs induces a lower demand for the other one. In addition, the size of the input elasticities with respect to the output prices reveals that the demand for fertilizers/pesticides is more responsive to the price of other crops, while the contrary is true for the demand for labour. Moreover, if we compare the cross-price elasticities of fertilizers/pesticides (FP) and labour (L) (e.g., $\left|\varepsilon_{FP,HL}\right| > \left|\varepsilon_{HL,FP}\right|$), we confirm the labour-intensive feature of the agricultural production system in Tanzania. The cross-price elasticities of the output supply to the input prices are always negative: this is consistent with the economic theory. Finally, consistent with the fact that labour accounts for about 70% of the total input costs, its own-price elasticity results as larger than for the other inputs.

We now turn to the netput elasticities with respect to the quasi-fixed inputs. A 1% increase in the hectares of land raises the profit by 0.7571%, while the same increase in the use of ox-ploughs produces a 0.4016% increase in profit; improved seeds and irrigation do not affect the profit significantly. All the netput elasticities with respect to land and ox-ploughs are positive, meaning that a larger portion of land or greater use of ox-ploughs is likely to be combined with a larger demand for both variable inputs (labour and fertilizers/pesticides), although only the elasticities associated with 'land' and 'ox-plough' are statistically significant. All this helps the production of cereals and other crops to increase. Finally, an increase in land is associated with larger changes in the supply of outputs and the demand for inputs.

[INSERT TABLE 3]

4.4 Consumption

Table 4 shows the coefficients of the AID system separately for farmers and non-farmers. Farmers and non-farmers can indeed differ in terms of consumption behaviour and, according to our agricultural household model, we look at the leisure component only for farm households. Most of the estimated parameters are highly significant.

The signs of the own-price and income (expenditure) elasticities, reported in Table 5, are consistent with the theory and their magnitudes are within the expected ranges. The demand for cereals is quite irresponsive to changes in their own price; this is particularly true for farmers as their cereal consumption partly derives from their own production. The demand for starches, vegetables and fruits (the second category) is more elastic to their own price change, both for farmers and for non-farmers. The demand for non-food items is quite insensitive to their own price variation. As regards the demand for leisure (estimated only for farm households), its own price elasticity is less than unitary, while its income elasticity is quite large and probably indicates that, as their income increases, people allocate proportionately more time to leisure and reduce their time allocation to work activities.

[INSERT TABLE 4]

[INSERT TABLE 5]

4.5 The Labour Market

The estimates for the off-farm supplied and on-farm hired labour markets are shown in Table 6. As discussed above, coefficients β_1^s and β_1^h in (26) and (27) capture the degree of market imperfections due to NTCs and heterogeneity. These coefficients are both statistically significant and take the expected sign (-8.13 and 34.31, respectively). Increasing the off-farm labour supply decreases the marginal revenues (i.e., a concave labour revenue function) with an average elasticity of -0.517; decreasing the on-farm hired labour generates an increase in the marginal costs (i.e., a convex labour cost function) with an average elasticity of 1.396. These results further corroborate the hypothesis that our estimated AHM is non-separable as both coefficients are statistically different from zero.

[INSERT TABLE 6]

5. Simulation of Agricultural Policies and Price Changes

5.1 Description of Agricultural Policies and Price Variation Simulations

The estimated model is used to assess the impact on household welfare of the implementation of different agricultural policies and the change in the price of cereals and other crops. These scenarios can be of particular interest in a country like Tanzania, where phase 1 of the Agricultural Sector Development Programme (ASDP) was launched in 2006/2007 and concluded in 2012/2013 and where a large increase in food prices was experienced during the food crisis in 2008. These scenarios are likely to have been affecting Tanzanian households, particularly in rural areas. The simulations will be applied to the *status quo* (baseline) without considering other changes that have taken place since the model's reference year, i.e., 2008–2009.

The priority actions within the ASDP are increasing the use of modern inputs and technologies (i.e., irrigation, improved seeds, erosion control, chemical fertilizers and ox-ploughs), improving support services (including agricultural research and extension services) and providing better agricultural marketing infrastructures as well as formal and informal credit institutions.

The simulations proposed in this study do not aim to replicate exactly the implemented policies and the price change actually experienced. This study rather intends to provide a comprehensive analytical tool that can be used to estimate the welfare effects of illustrative agricultural policies and food price changes.

Specifically, in this study, we first simulate an increase in the price of cereals and in the price of other crops of 40% (which can be roughly considered as a lower bound of the price variation experienced by many developing countries between 2007 and 2008) for both producers and consumers. In addition, we simulate an increase of 10% in the available arable land and an increase of 10% in the use of ox-ploughs for all households. For this analysis, we do not take into account the cost of these two policies, so we are not able to say which intervention has the most potentially poverty-reducing effects per Tanzanian shillings spent. This would far exceed the scope of this paper.

The scenario simulating a land increase is motivated by fact that the Tanzanian Government has recently recognized that the access to land and the sticky land market represent a crucial issue for the country. This is why the Tanzanian Ministry of Lands, Housing and Human Settlement Development is involved in a significant number of projects to implement Tanzania's land law reform, which has been enforced since May 2001. However, its implementation is slow and geographically uneven, and not much is known about how the reform is affecting the distribution of land. An increase in the mechanization of agricultural processes through the use of ox-ploughs is part of the ASDP reform[21].

The discussion that follows focuses on farmer households as the theoretical framework followed in this study as well as the proposed scenarios primarily have

[21] Among other interventions, the ASDP aims at increasing the proportion of farm households using ox-ploughs from 7.5 to 30%.

implications for them; the results for non-farmers are provided for the price rise scenario.

5.2 Poverty Estimates

The first simulation shows that a 40% increase in cereals' prices has a likely substantial negative effect on households, both for farmers and for non-farmers (see Table 7). When only the direct effect is taken into account (that is, without the substitution effect – the first component of (28)), the headcount poverty for farmers increases from 18.98% to 24.02% and for non-farm households from 10.67% to 13.80%. When the substitution effect is incorporated (the second component of (28)), the poverty among farmers decreases to 22.26%, while for non-farmers it does not change. The poverty gap shows a similar pattern except for the case of non-farmers, where it additionally rises when second-order effects are incorporated. Farmers are more able than non-farmers to adjust their consumption patterns following a rise in the price of cereals and have less room to compress their already squeezed consumption of non-food items. Differently, non-farmers are more able to reduce their non-food consumption (possibly their less essential demand) – see the negative cross-price elasticity of the non-food category with respect to the price of cereals – in order to keep their food consumption as little altered as possible. Furthermore, non-farmers reduce their demand for cereals relatively more (see the own-price elasticity) as they cannot rely on own consumption, and substitute it with other food items (the cross-price elasticities are indeed higher for non-farmers).

If the poverty changes are assessed over a relatively large range of poverty lines (i.e., between 50 and 150% of the poverty line) – see Figure 1 – for farmers, the poverty headcount associated with the direct effect always lies above the poverty estimated with the full price effect (i.e., the poverty curve linked to the full price effect dominates the poverty curve on the direct effect). As for non-farmers (see Figure 2), we cannot say whether the full or the direct price effect dominates as the two curves cross each other at different values of the poverty line. The poverty gap follows a similar pattern, but with clearly dominant results (in the sense of stochastic dominance) for both farm and non-farm households. In general, while we find that for farm households the increase in food prices has a relatively minor effect on poverty, the increase in farm profit following the hike in food prices is not enough to neutralize the negative effect on real consumption. As depicted in Figure 3 (first graph), the average deterioration in consumption is larger than the average improvement in the profit from farming activities. This is particularly true for poorer percentiles, while it does not depend on which theoretical model is adopted (the non-separable versus the separable household model). Figure 4 confirms that farm households are on average net consumers of rice; in particular, around the poverty line, farm households consume around 25% and produce only 5% of their total consumption, resulting in net consumption of rice of nearly 20%. This implicates a large negative first-order effect following a 40% increase in the price of rice and a moderate positive indirect effect. Consistent with the size and the sign of the production and consumption elasticities shown in Table 8 (i.e., incentives to increase agricultural production and some substitution effects between consumption goods), the indirect effect helps to cushion the negative effects on poverty only to a certain degree (see Table 7).

If we compare the results simulated under a non-separable AHM framework with those obtained under a separable model, under a non-separable model the poverty gap is only 0.01 percentage points lower, whereas no differences are found in terms of incidence of poverty (see Table 9). Even when we distinguish between the production and the consumption component, no important differences emerge (we can only note that the production component under the non-separable model is marginally higher, especially for the poorest percentiles (see the first graph in Figure 3)). This result is mainly explained by the low price elasticity of the shadow wage with respect to the price of cereals (its average value is -0.0369, Table 8), which results in minimal differences in consumption elasticities between the separable and the non-separable model (this difference is given by the third component of (10)). On the production side, the price elasticities (of outputs and inputs) are larger under the non-separable model; while the production of both cereals and other products grows faster than under the separable model, the demand for inputs rises faster as well. All in all, the variation in agricultural revenue does not differ substantially between the two approaches. However, the differences between the results under a non-separable and a separable model are commodity- or product-specific. For comparison purposes, we simulate a 40% increase in the price of other crops as well. This would induce an increase in the poverty headcount to 23.26% (and the poverty gap to 6.08%) when a non-separable AHM is adopted, compared with 22.94% (and 6.00% for the poverty gap) when a separable AHM is used (results are not reported and not discussed more deeply for lack of space).

As it could be expected from the values of the elasticities (Table 8, columns 3–6), the effect of changes in quasi-fixed inputs on household welfare and poverty differ significantly between the non-separable and the separable approach, with the second generating a larger reduction in poverty rates. When a non-separable model is adopted, the poverty headcount drops to 16.55% and 17.62% following a 10% rise in land availability and in the use of ox-ploughs, respectively. When a separable framework is followed (second column in Table 9), the poverty reduction is even greater (15.77% and 17.11%, respectively). This difference between the two approaches is mainly driven by the production side (see Figure 3, second and third graphs). In the non-separable model, the negative (indirect) price effect affecting agricultural profit through the subsequent change in the shadow wage is greater than the positive (direct) effect on production generated by an increase in the quasi-fixed inputs. As shown in Table 8 (columns 3–6), production-related elasticities are negative for the non-separable model and positive for the separable framework. In the non-separable framework, all this results in a negative variation in profit, which is, in the scenario of land increase, about -2% for the poorest percentiles (and progressively less negative for richer households). On the contrary, the indirect effect on consumption is positive, which then results in a variation in the consumption component that is greater under the non-separable model than under the separable framework. The final effect on household welfare does then depend on whether the production effect prevails over the consumption effect. When the increase in the use of ox-ploughs is simulated, a similar pattern is found, though with smaller variations given the smaller size of the elasticities[22].

By summing up, the total effect on household welfare as effect of changes in land and ox-ploughs availability is then found to be positive (i.e., generating a decrease in the poverty rate). This is the case also under the non-separable AHM, where the positive variation in consumption levels more than compensates the decrease in profits. Such

[22] In order to check for the sensitivity of the parameters' value, we test how the poverty estimates change when all netputs and commodities' elasticities (ε_{nv}^{nsAHM}, Θ_{iv}^{nsAHM}, $\varepsilon_{nz_k}^{nsAHM}$, $\Theta_{iz_k}^{nsAHM}$) – elasticity by elasticity – range between 90 and 110% of their estimated punctual value. This is done for the estimates under the non-separable AHM model only. Headcount poverty figures are found robust (i.e., the difference between the headcount estimated with the punctual elasticities and those with the modified elasticities is never statistically significant). As for the poverty gap, the difference between the headcount estimated with the punctual elasticities and those with the modified elasticities is statistically significant for netputs 1 and 4, and commodities 1-4. However, it should be noted that such differences in the poverty gap are extremely low – with the largest ranges (between 0.0001 and -0.0002) being under the land simulation.

reduction is driven by the negative effects on netputs and induced by higher labor costs. When land and ox-plough increase, the shadow wage increases; this is expected as such investments in quasi-fixed inputs are likely to increase the productivity of labour (which is reflected into higher shadow wages). However, as the netputs' changes with respect to the price of labour are found to be quite elastic (and negative), the indirect component (i.e., that is unique to the non-separable AHM) more than compensates the (positive) direct effect of quasi-fixed inputs on netputs. These results are similar to what Sonoda and Maruyama (1999) found as the effect of the increase in the price of rice (i.e., under a non-separable approach, contrary to a separable approach, the supply of rice decreases due to the increase in its price because of the negative effects played by the shadow wage). Of course, our results are driven by the importance of the labour input over the net profits (see the formula of netputs' elasticities (21) and (22)). Everything being equal, as long as the labour share decreases (as effect of land/ox-plough increase), the changes in netputs' supply/demand with respect to the shadow wage will be less elastic. In the longer term, this process might finally revert the sign of the change in the production levels due to a variation in land or ox-ploughs availability.

When the leisure component in the consumption model (AID System estimation) is not taken into account (i.e., 4 consumption categories) – as is normal in the literature – the price effect on household welfare is somewhat lower (the incidence of poverty and the poverty gap rise to 21.91 and 5.73, respectively) and the effect of the increase in quasi-fixed inputs is even greater than when the leisure component is considered. This is mainly due to the differences in the price elasticities with respect to the price of cereals (the first term in (10) and (15)).

It is finally useful to discuss what drives the differences between the separable and non-separable approaches. This is related to the adjustment in the shadow wage following an exogenous shock. This captures what we called the indirect effect, which adds to the direct effect. In the case where a shock (positive or negative) does not affect the shadow wage, then the separable and non-separable models produce the same results. On the contrary, when the shadow wage adjusts following a shock, the following results may occur under a non-separable AHM: (1) the changes in netputs' supply/demand and commodities' demand be stronger (i.e., more positive/negative) than under a separable AHM; this happens when the indirect effect goes in the same direction as the direct effect and, therefore, the indirect effect reinforces the direct effect. (2) The changes in netputs' supply/demand and commodities' demand be weaker (i.e., less positive/negative); this is the case when the indirect effect goes in the opposite direction than the direct effect and, therefore, the indirect effect weakens the direct effect. In the latter case, when the shadow wage is particularly sensitive to exogenous shocks, the indirect effect may dominate the direct effect; in such a case, the changes in netputs' supply/demand and commodities' demand under the non-separable AHM are opposite to the case when a separable AHM is used.

[INSERT TABLE 7]
[INSERT TABLE 8]
[INSERT TABLE 9]

[INSERT FIGURE 1]
[INSERT FIGURE 2]
[INSERT FIGURE 3]
[INSERT FIGURE 4]

6 Conclusions

Building on the renewed interest in the importance of the role of the agricultural sector in the development process by both the scientific and the policy community, this paper analyses the effect of large food price changes and structural interventions on agricultural households' welfare. This can be particularly relevant in a context such as Tanzania, where the Government has recently recognized the pivotal role of agriculture in reducing poverty and designed an Agricultural Sector Development Programme (ASDP).

However, the estimation of the potential impact of agricultural policies or price changes on agricultural households' welfare can be complex because farmers' consumption, production and labour market decisions are often interlinked and markets are missing or imperfect. With this premise, in this study, we proposed a comprehensive and flexible tool that takes into account the second-order effects generated by exogenous shocks. Such effects include the direct impact on the supply and demand reactions due to the shock and the indirect impact on the supply and demand adjustments to the endogenous variations in the shadow wage produced by the shock. This approach was then applied to Tanzania and used to simulate the effect on household welfare of a hypothetical 40% increase in the price of cereals and other crops and a hypothetical 10% increase in the hectares of arable land and in the use of ox-ploughs.

This study showed that neglecting the second-order effects in consumption and production decisions (which affect demand and supply decisions both directly and indirectly through the shadow wage) due to positive or negative shocks can bias the final impact on household welfare. This can clearly have important empirical and policy implications. Specifically, the extent to which separable and non-separable models differ depends on how sensitive the shadow wage is to changes in exogenous prices or inputs and to the degree of substitutability between commodities and leisure (on the consumption side) as well as between netputs and labour (on the production side). We found that the production and consumption elasticities of the shadow wage with respect to the price of cereals are quite low, resulting in negligible differences between the results obtained under a non-separable and a separable model. Given the larger elasticity of the shadow wage with respect to the price of other crops, the two approaches give different results, with the non-separable model resulting in a greater deterioration of households' welfare. Finally, such differences are quite important for the case of a change in quasi-fixed inputs, with the non-separable approach resulting in smaller welfare improvements due to the negative effects on profits generated by the endogenous change in the shadow wages.

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Appendix: Tables

Table 1. *Production Function Estimates*

	loutput_value		First stage estimates				
	OLS	IV	lhh_pesticides	lhh_inorganic_fert	lhh_organic_fert	lhired_female	lhired_male
Independent variables	Coef. [b]	Coef. [b]	Coef. [b]	Coef. [b]	Coef. [b]	Coef. [b]	Coef. [b]
lhh_pesticides[a]	0.029	-0.301					
lhh_inorganic_fert[a]	0.174***	0.403					
lhh_organic_fert[a]	0.018*	0.193*					
lhired_female[a]	0.139***	0.048					
lhired_male[a]	0.064**	0.163					
lhh_land	0.532***	0.552***	0.193***	0.154*	0.030	0.554***	0.386***
lhh_tot_lab_f	0.064***	0.077**	0.020	0.020	-0.109***	-0.087***	0.011
lhh_tot_lab_m	0.099***	0.118**	0.036***	-0.006	-0.023	0.018	-0.041**
hh_head_age	-0.005	-0.017	-0.001	-0.003	0.043*	-0.024**	-0.021*
hhhead_age^2	-0.000	0.000	0.000	0.000	0.000	0.000	0.000*
hh_head_sex	-0.107	-0.167	-0.026	0.103	-0.025	-0.167	0.150*
illiterate	0.004	0.175	-0.082**	-0.398***	-0.604***	-0.207***	-0.111*
land_quality	0.325***	0.352***	0.068**	-0.024	0.007	-0.046	0.013
irrigation	0.338*	0.148	0.561***	1.007*	0.721	0.372	0.699***
lroad	-0.046	-0.003	0.001	-0.067	-0.169	-0.051	-0.070
lmarket	0.038	0.001	-0.047**	0.018	0.121**	0.038	0.024
lmechanization	0.085***	0.055**	0.006	0.020	0.160***	0.064***	0.037**
Instruments:							
nchildren			-0.012	-0.022	-0.067**	-0.073***	-0.044***
nelderlies			-0.001	-0.126	0.056	0.045	-0.060
nadults_f			0.034	-0.021	0.191***	0.083**	0.054
nadults_m			-0.039	-0.033	0.208***	-0.001	-0.050
lprice_cereals			0.082*	-0.321**	-0.101	0.140	-0.059
owner			0.050	-0.096	0.309*	-0.394***	-0.233**
water			0.005	0.369**	0.182	0.279***	0.053
fuel			0.105	-0.470	0.398	0.269	-0.100
cons	8.757***	8.969***	-0.855**	2.135**	-1.301	0.415	0.890*
R^2	37.65	18.73	0.091	0.059	0.090	0.127	0.082
N				1860			

IV test results

Wooldridge's robust score: chi-sq(5)=8.179**

Robust regression-based: F(5,1830)=2.703**

Wooldridge's robust score: chi-sq(3)=5.8195

[a] Variables treated as endogenous in the instrumental variable estimation. [b] with robust to clustering standard errors.

Notes: (***), (**), (*) significant at 0.01, 0.05 and 0.10 level respectively; the estimations also include eight district level dummies (their coefficients are not shown in the table for lack of space). For variables' definition and descriptive statistics see Table 10.

Source: Authors' estimations using TNPS-1 (see GoT, 2010)

Table 2. *Restricted Parameters Estimates Of The Translog Profit Function*

			Price of							
		Intercept	**Cereals (LnP_1)**	**Fertilizers& pesticides (LnP_2)**	**Labour (LnP_3)**	**Other crops (LnP_4)**	**Improved seeds (LnZ_1)**	**Land (LnZ_2)**	**ox-plough (LnZ_3)**	**irrigation (LnZ_4)**
Share (S_i) function	**Cereals**	0.354	-0.132	0.032	-0.192***	0.292**	-0.215***	0.004	0.186***	0.024
	Fertilizers&pesticides	0.177**	0.032	-0.015	0.000	-0.017	-0.022	-0.018	0.019	0.021
	Labour	0.239	-0.192***	0.000	0.059	0.132***	0.129***	-0.066	-0.034	-0.030
Profit Function		**Agro-zones dummies**	**(LnP_1)**	**(LnP_2)**	**(LnP_3)**	**(LnP_4)**	**(LnZ_1)**	**(LnZ_2)**	**(LnZ_3)**	**(LnZ_4)**
			0.354	0.177**	0.239	0.231	-0.161	0.757**	0.402**	0.003
		$(LnP_1)^2/2$	**$(LnP_2)^2/2$**	**$(LnP_3)^2/2$**	**$(LnP_4)^2/2$**	**LnP_1LnP_2**	**LnP_1LnP_3**	**LnP_1LnP_4**	**LnP_2LnP_3**	**LnP_2LnP_4**
		-0.132	-0.015	0.059	-0.407**	0.032	-0.191***	0.292**	0.000	-0.017
		LnP_3LnP_4	**LnP_1LnZ_1**	**LnP_1LnZ_2**	**LnP_1LnZ_3**	**LnP_1LnZ_4**	**LnP_2LnZ_1**	**LnP_2LnZ_2**	**LnP_2LnZ_3**	**LnP_2LnZ_4**
		0.132***	-0.215**	0.004	0.186***	0.024	-0.022	-0.018	0.019	0.021
		LnP_3LnZ_1	**LnP_3LnZ_2**	**LnP_3LnZ_3**	**LnP_3LnZ_4**	**LnP_4LnZ_1**	**LnP_4LnZ_2**	**LnP_4LnZ_3**	**LnP_4LnZ_4**	**$(LnZ_1)^2/2$**
		0.129***	-0.066	-0.034	-0.030	0.107	0.079	-0.171***	-0.015	0.142
		$(LnZ_2)^2/2$	**$(LnZ_3)^2/2$**	**$(LnZ_4)^2/2$**	**LnZ_1LnZ_2**	**LnZ_1LnZ_3**	**LnZ_1LnZ_4**	**LnZ_2LnZ_3**	**LnZ_2LnZ_4**	**LnZ_3LnZ_4**
		-0.020	0.089***	0.034	-0.008	-0.074*	-0.060	-0.007	0.035	-0.009

Notes: (***), (**), (*) significant at 0.01, 0.05 and 0.10 level respectively. Coefficients are estimated with robust to clustering standard errors. The estimations are controlled for the four agro-zones in Tanzania (coefficients are not reported here). The number of observations used for this estimation is 1,589 (as only households with non-negative profits are included – see in the text for more details). For variables' definition and descriptive statistics see Table 10.

Convexity is fulfilled by 95.7% of observations; monotonicity is fulfilled by 77.7% of observations. The convexity and monotonicity tests are run through the R-package 'micEcon' (Henningsen, 2014a)

Source: Authors' estimations using TNPS-1 (see GoT, 2010)

Table 3. *Output and Input Price Elasticity Matrix*

		Price of							
		Cereals	**Fertilizers& pesticides**	**Labour**	**Other crops**	**Improved seeds**	**Land**	**ox-plough**	**irrigation**
Quantity of	**Cereals**	0.3820	-0.5886***	-1.5731***	1.7798***	-0.1994	0.7575**	0.4278**	0.0140
	Fertilizers& pesticides	1.4196***	-1.5852***	-1.4435***	1.6091***	-0.0176	0.7837**	0.2705*	-0.0366
	Labour	1.6047***	-0.6106***	-2.4839***	1.4898***	-0.1429	0.8001***	0.3247**	0.0181
	Other crops	1.6565***	-0.6210***	-1.3594***	0.3238*	0.0147	0.8046***	0.1929	-0.0123
	Profit	0.3538	0.1765**	0.2391	0.2305	-0.1614	0.7571**	0.4016**	0.0027

Notes: (***), (**), (*) 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). Elasticities are estimated at the weighted average of output and input shares.

Source: Authors' estimations using TNPS-1 (see GoT, 2010)

Table 4. *AID System Estimates*

Share Equation (w_i) of	intercept	expenditure	lnP_C$_i$ - (ln) Price of C$_1$	C$_2$	C$_3$	C$_4$	C$_5$
Farmers							
C$_1$	-0.10879	-0.0248***	0.1066***				
C$_2$	0.4448***	-0.0552***	-0.0042	-0.0571			
C$_3$	0.1889**	0.0303***	-0.0371*	0.0178	0.0290		
C$_4$	0.1871	-0.0159***	-0.0424**	0.0462*	-0.0052	0.0034	
C$_5$	0.2879***	0.0657***	-0.0228***	-0.0027	-0.0044	-0.0020	0.0320***
Non-farmers							
C$_1$	-0.5243*	-0.0351***	0.0633				
C$_2$	0.1015	-0.0561***	0.0712*	-0.0910			
C$_3$	0.2278	0.0400***	-0.0185	0.0457	-0.0319		
C$_4$	1.1949***	0.0511***	-0.1161***	-0.0259	0.0046	0.1374**	

Notes: (***), (**), (*) significant at 0.01, 0.05 and 0.10 level respectively; C_1 = maize and other cereals; C_2 = starches, pulses, dry nuts, seeds, vegetables, fruits, oil and fats; C_3 = sugar, sweets, meat, eggs, dairy, fish, salt, spices and beverages; C_4 = non-food; C_5 = leisure. Observations used in estimate for farmers are 1860 and 1328 for non-farmers. For variables' definition and descriptive statistics see Table 10.

Concavity is fulfilled by 97.40% of observations and 100% of observations in the farmers' and non-farmers' estimations respectively; monotonicity is fulfilled by 99.09% and 99.93% of observations respectively. The concavity and monotonicity tests are run through the R-package 'micEconAids' (Henningsen, 2014b).

Coefficients are estimated with robust to clustering standard errors.

Source: Authors' estimations using TNPS-1 (see GoT, 2010)

Table 5. *Expenditure Price and Expenditure Elasticity Matrix*

Quantity of	Compensated Price elasticity					Uncompensated Price elasticity					
	C_1	**C_2**	**C_3**	**C_4**	**C_5**	**C_1**	**C_2**	**C_3**	**C_4**	**C_5**	**Expenditure**
	Farmers										
C_1	-0.2981***	0.2273	0.0365**	0.0571***	-0.0228***	-0.4904***	-0.0031***	-0.1417	-0.1765	-0.0739	0.8856***
C_2	0.1894	-0.9845***	0.2817**	0.4207***	0.0926***	0.0184***	-1.1893***	0.1232***	0.2130***	0.0472***	0.7875***
C_3	0.0408***	0.3665	-0.6628***	0.2524***	0.0031	-0.2092	0.0672***	-0.8944***	-0.0511	-0.0632***	1.1507***
C_4	0.0531***	0.4285**	0.1845***	-0.7291***	0.0630***	-0.1510**	0.1842***	-0.0046	-0.9770***	0.0088***	0.9396***
C_5	-0.1169	0.3451***	0.0610	0.3420	-0.6312***	-0.5820	-0.2118***	-0.3700***	-0.2228***	-0.7545***	2.1410***
	Non-farmers										
C_1	-0.4811***	0.5905***	0.1254	-0.2348***		-0.6559***	0.3912***	-0.0593	-0.5086**		0.8327***
C_2	0.5178***	-1.1245***	0.4013*	0.2054		0.3571***	-1.3078***	0.2315***	-0.0463**		0.7655***
C_3	0.1187*	0.4331	-0.9130***	0.3612		-0.1292	0.1504***	-1.1749***	-0.0270***		1.1807***
C_4	-0.1499***	0.1495*	0.2437	-0.2433***		-0.3925**	-0.1272**	-0.0127**	-0.6233**		1.1557***

Note: (***), (**), (*) 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). C_1 = maize and other cereals; C_2 = starches, pulses, dry nuts, seeds, vegetables, fruits, oil and fats; C_3 = sugar, sweets, meat, eggs, dairy, fish, salt, spices and beverages; C_4 = non-food; C_5 = leisure. For variables' definition and descriptive statistics see Table 10.

Source: Authors' estimations using TNPS-1 (see GoT, 2010)

Table 6. *Estimation of labour market equations*

	labor supply		labor demand	
	bivariate (y_s)	2nd stage of 2SLS	bivariate (y_h)	2nd stage of 2SLS
X_L^s (as predicted in first stage)		-8.12714*		
X_L^h (as predicted in first stage)				34.31075***
nchildren	-0.0188		-0.04977***	
nadults	0.12379***	8.45583	-0.025	
nelderlies	-0.06194	182.38077	0.06107	
hhhead_sex	0.04548	408.34649	-0.0596	
hhhead_age	-0.02542**	108.86545	-0.02708*	
hhhead_age2	0.00013	-1.04716	0.00018	
hh_land	0.00981*		0.02179**	
mechanization	-0.00000***		0.00000	
k_intensity	0.01020***		0.01989*	-2.79333**
P1	0.00061*		-0.00041	
P2	-0.00000		-0.00000	
P4	-0.00013		0.00006	
n_bike	0.20132***	-1.04e+03*	0.40819***	-2.12e+03**
notwork_rate	-0.00781**	15.09553	-0.00446	8.14353
road_clust	0.00774	6.77951	-0.04394*	222.73626*
tel_region	0.27168	1.23E+03	0.18984	2.17E+03
urban_region	0.01388**	-13.45427	0.00993**	-19.05016
mkt_wage	0.00012***	0.22512	0.00001	0.68258
IMR supply		-4.15E+03		
IMR demand				-4.33e+03**
constant	0.22712	2.05E+03	0.61711*	1.86E+03
rho	0.08455**		0.08455**	
N	1931	982	1931	730

Notes: For variables' definition and descriptive statistics see Table 10. Coefficients are estimated with robust to clustering standard errors.

Source: Authors' estimations using TNPS-1 (see GoT, 2010)

Table 7. *Poverty Estimations, Base Year And Simulations*

farmers	Incidence of poverty	Poverty Gap
base year	18.98	4.82
cereal price effect - total	**22.26**	**5.83**
cereal price effect – first order	**24.02**	**6.34**
land increase	**16.55**	**4.08**
ox increase	**17.62**	**4.44**
non-farmers		
base year	10.67	2.76
cereal price effect - total	**13.80**	**3.50**
cereal price effect – first order	**13.80**	**3.53**

Note: figures in bold identify a statistically significant difference (at 5%) compared with the base year. These figures are estimated with DASP (Araar and Duclos, 2007).

Source: Authors' estimations using TNPS-1 (see GoT, 2010)

Table 8. *Elasticities under non-separable and separable agricultural household model*

	Price of cereals		land increase		ox-plough increase	
	non-separable	separable	non-separable	separable	non-separable	separable
ψ (average)	-0.03694		1.25309		0.64549	
ψ (supply&hire)	-0.03378		1.14594		0.59030	
ψ (only supply)	-0.03496		1.18569		0.61078	
ψ (only hire)	-0.03900		1.32298		0.68150	
ψ (autarkic)	-0.04087		1.38626		0.71409	
$\varepsilon_{n=1}$	0.43986	0.3820	-1.20562	0.7575	-0.58343	0.4278
$\varepsilon_{n=2}$	1.47271	1.4196	-1.01768	0.7837	-0.65741	0.2705
$\varepsilon_{n=3}$	1.69609	1.6047	-2.29968	0.8001	-1.27208	0.3247
$\varepsilon_{n=4}$	1.70655	1.6565	-0.89173	0.8046	-0.68093	0.1929
$\Theta_{i=1}$	-0.45874	-0.4596	0.64201	0.6705	0.34092	0.3556
$\Theta_{i=2}$	0.04239	0.0458	0.71179	0.5962	0.37574	0.3162
$\Theta_{i=3}$	-0.16923	-0.1691	0.87512	0.8713	0.46406	0.4621
$\Theta_{i=4}$	-0.12063	-0.1183	0.78999	0.7114	0.41778	0.3773
$\Theta_{i=5}$	-0.48420	-0.5074	0.83344	1.6211	0.45401	0.8597

Notes: 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

Source: Authors' estimations using TNPS-1 (see GoT, 2010)

Table 9. *Poverty effects under non-separable and separable agricultural household model of different simulations*

	Incidence of poverty			Poverty Gap		
farmers	non-separable	separable(1)	separable(2)	non-separable	separable(1)	separable(2)
base		18.98			4.82	
cereal price effect - total	**22.26**	**22.26**	**21.91**	**5.83**	**5.84**	**5.73**
land increase	**16.55**	**15.77**	**15.67**	**4.08**	**3.81**	**3.75**
ox increase	**17.62**	**17.11**	**16.88**	**4.44**	**4.28**	**4.25**

Notes: "separable(1)" identifies a separable model where the leisure component is considered; "separable(2)" uses a separable model where the leisure component is not introduced; figures in bold identify a statistically significant difference (at 5%) compared with the base year. These figures are estimated with DASP (Araar and Duclos, 2007)

Table 10. *Definition, mean and standard deviation of the variables presented in the previous tables*

variables used in Table 1	**variables' definition**	**mean**	**std.dev**
loutput_value	value of total agricultural production (in log)	11.74	1.34
lhh_land	acres of cultivated land at the hh level (in log)	1.57	0.74
lhh_tot_lab_f	total days by adult women (15-60 years old) on on-farm family labour (in log)	3.81	1.39
lhh_tot_lab_m	total days by adult men (15-60 years old) on on-farm family labour (in log)	3.36	1.85
hhhead_age	age of the hh head (in years)	47.33	15.76
hhhead_age2	square of age of the hh head (in years)	2487.88	1645.10
hhhead_sex	sex of the hh head (1=male; 0=female)	0.75	0.43
illiterate	binary variable taking value 1 if hh head is illiterate	0.27	0.45
land_quality	hh mean (weighted by plot size) value of soil quality of the plot (1=bad;2=average;3=good)	2.44	0.52
irrigation	hh mean (weighted by plot size) of irrigated plots	0.02	0.13
lroad	hh mean of distance (km) of plot to road (in log)	0.84	0.67
lmarket	hh mean of distance (km) of plot to market (in log)	1.63	1.00
lmechanization	value of farm implements used by the hh (in log)	9.29	2.26
lhh_pesticides	quantity (kg or l) of pesticides used by hh (in log)	0.18	0.63
lhh_inorganic_fert	quantity (kg) of inorganic fertilizers used by hh (in log)	0.58	1.53
lhh_organic_fert	quantity (kg) of organic fertilizers used by hh (in log)	1.21	2.50
lhired_female	total days by hired women on on-farm activities (in log)	0.98	1.41
lhired_male	total days by hired men on on-farm activities (in log)	0.71	1.25
district 1		0.20	
district 2		0.22	
district 3		0.16	
district 4		0.14	
district 5		0.14	
district 6		0.09	
district 7		0.03	
district 8		0.02	
nchildren	number of children in the hh	2.50	1.96
nelderlies	number of elderlies in the hh	0.33	0.60
nadults_f	number of female adults in the hh	1.32	0.90
nadults_m	number of male adults in the hh	1.24	1.00
lprice_cereals	price of cereals (in log)	5.35	0.36
owner	home ownership dummy (=1 if hh owns its home)	0.92	0.28
water	source of drinking water dummy (=1 if hh has piped water)	0.06	0.24
fuel	cooking fuel dummy (=1 if gas or electricity)	0.00	0.06
variables used in Table 2			
ln_hh_profit_net	value of hh net profit (in log)	11.48	1.49
s_1	share of cereals (of net profit)	1.55	15.29
s_2	share of fertilizers&pesticides (of net profit)	-0.64	7.97
s_3	share of labour (of net profit)	-1.53	15.12
s_4	share of other crops (of net profit)	1.62	6.60
lnP1	producer price of cereals (in log)	5.34	0.36
lnP2	price of fertilizers&pesticides (in log)	5.91	2.50

lnP3	(shadow) price of labour (in log)	6.03	1.00
lnP4	producer price of other crops (in log)	5.94	0.41
lnZ1	probability of using improved seeds (in log)	-2.11	0.83
lnZ2	hectares of cultivated land (in log)	1.58	0.73
lnZ3	probability of using an ox-plough (in log)	-3.37	1.46
lnZ4	probability of owning irrigated plots (in log)	-3.97	1.29
variables used in Table 4 (farmers)			
w_1	budget share of cereals	0.22	0.15
w_2	budget share of other crops	0.28	0.18
w_3	budget share of dairy&meat	0.18	0.13
w_4	budget share of leisure	0.11	0.16
w_5	budget share of non-food commodities	0.20	0.11
lnP_C1	price of cereals (in log)	6.74	0.17
lnP_C2	price of other crops (in log)	6.83	0.15
lnP_C3	price of dairy&meat (in log)	7.65	0.20
lnP_C4	(shadow) price of leisure (in log)	5.96	0.84
lnP_C5	price of non-food commodities (in log)	-0.05	0.06
ln_exp	total household expenditure (in log)	14.49	0.75
variables used in Table 4 (non-farmers)			
w_1	budget share of cereals	0.21	0.12
w_2	budget share of other crops	0.24	0.15
w_3	budget share of dairy&meat	0.22	0.13
w_4	budget share of non-food commodities	0.33	0.15
lnP_C1	price of cereals (in log)	6.81	0.13
lnP_C2	price of other crops (in log)	6.94	0.14
lnP_C3	price of dairy&meat (in log)	7.76	0.19
lnP_C4	price of non-food commodities (in log)	0.04	0.09
ln_exp	total household expenditure (in log)	14.70	0.90
variables used in Table 6			
y_s	dummy off-farm labour supply (=1 if the hh supplies off-farm labour)	0.54	0.50
h_h	dummy on-farm labour demand (=1 if the hh hires on-farm labour)	0.44	0.50
nchildren	number of children in the hh	2.50	1.96
nadults	number of adults in the hh	2.56	1.56
nelderlies	number of elderlies in the hh	0.33	0.60
hhhead_sex	sex of the hh head (1=male; 0=female)	0.75	0.43
hhhead_age	age of the hh head (in years)	47.36	15.70
hhhead_age2	square of age of the hh head (in years)	2489.63	1636.64
hh_land	acres of cultivated land at the hh level	7.03	19.12
mechanization	value of farm implements used by the hh (in 10,000)	185746.80	1557478.00
k_intensity	mechanization/hh_land	2.67	45.51
P1	producer price of cereals	228.42	99.15
P2	price of fertilizers&pesticides	3603.41	12058.31
P4	producer price of other crops	433.56	281.30
n_bike	number of bikes by the hh	0.44	0.50
notwork_rate	regional % rate of not working people (15-60 years old population)	38.29	12.29
road_clust	average distance (km) of plot to road at the cluster level	1.97	1.26

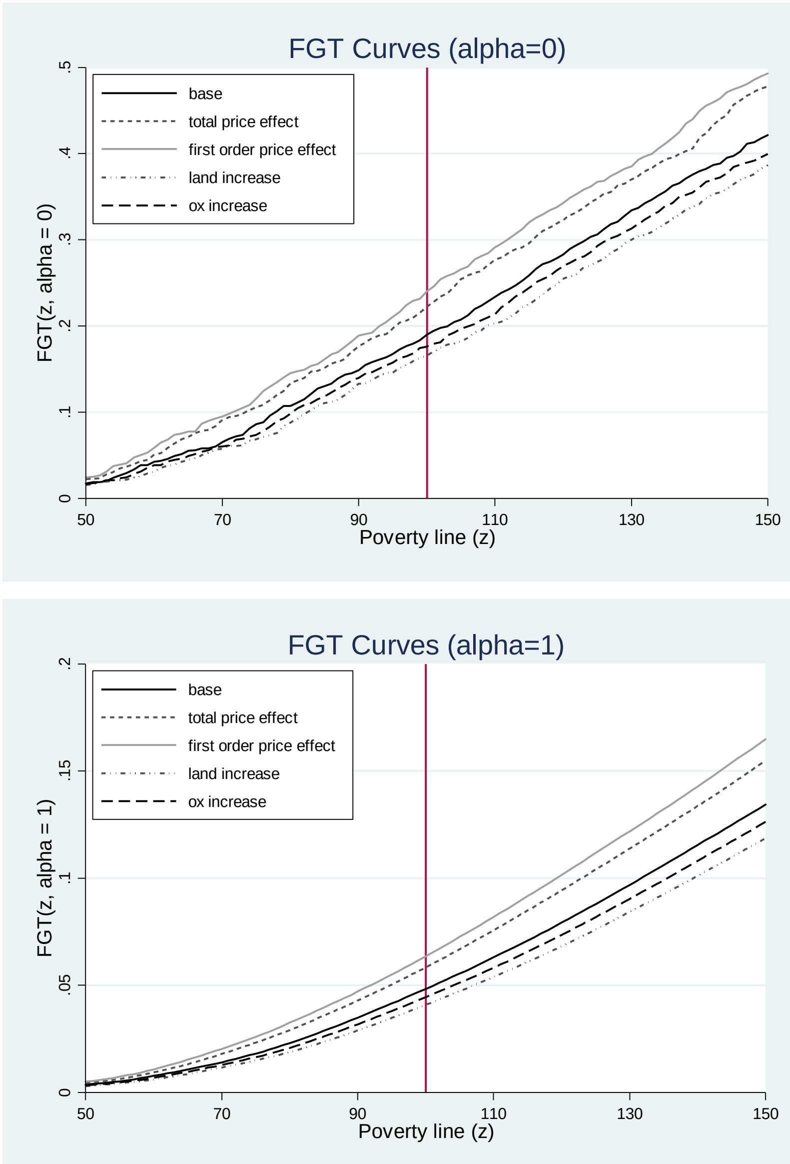
tel_region	regional % rate of telephones per hh	0.47	0.21
urban_region	regional % rate of urban hh	12.00	8.45
mkt_wage	median market wage at the cluster level	2277.16	1098.65

Notes: variables expressed in value are in Tanzanian shillings; agricultural-related variables are based on the data collected for the long-rainy season only.

Source: Authors' calculations using TNPS-1 (see GoT, 2010)

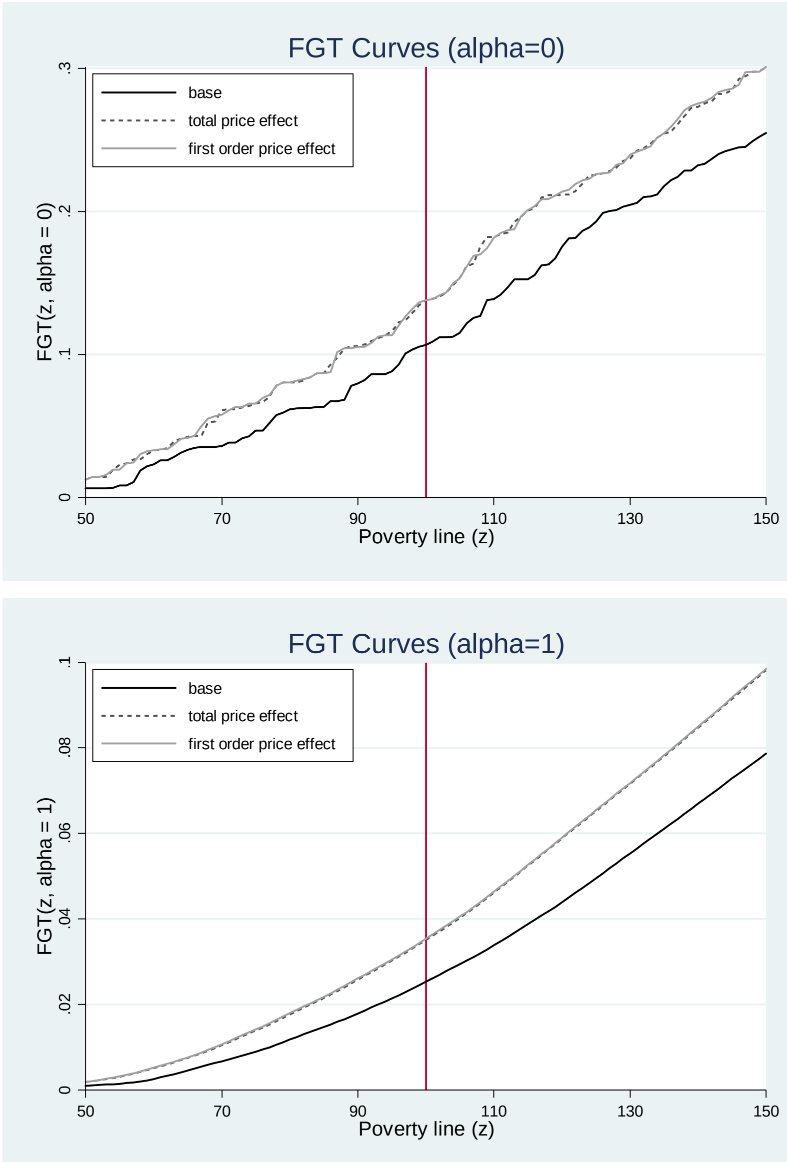
Appendix: Figures

Figure 1. *Poverty (FGT0 and FGT1) curves – farmers*



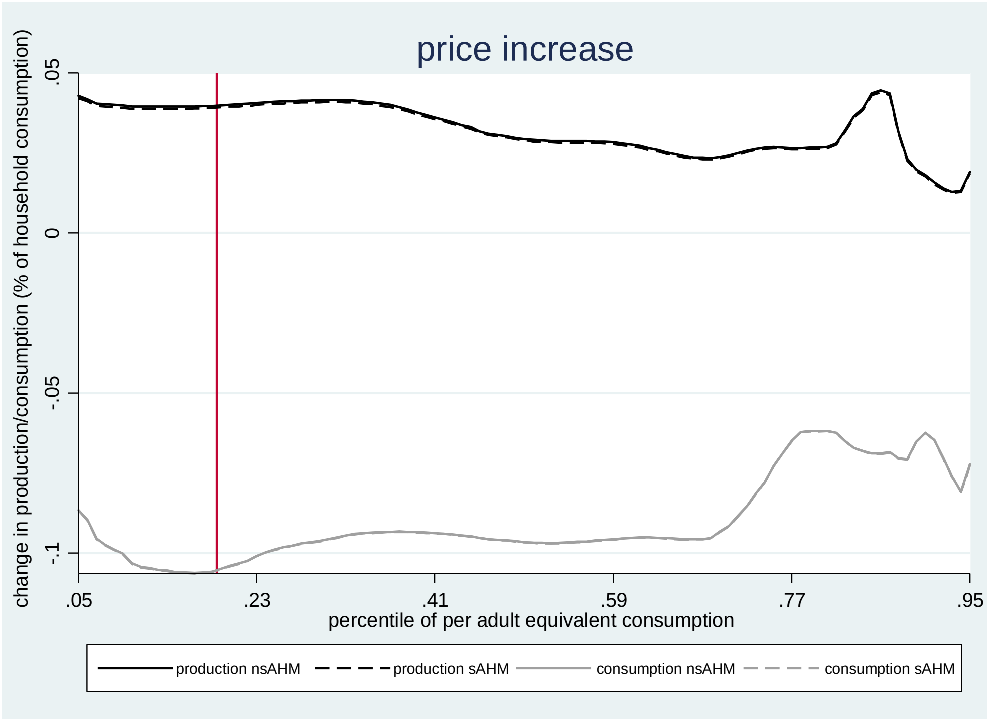
Note: Poverty line is normalized to 100. The graphs are drawn with DASP (Araar and Duclos, 2007)
Source: Authors' estimations using TNPS-1 (see GoT, 2010).

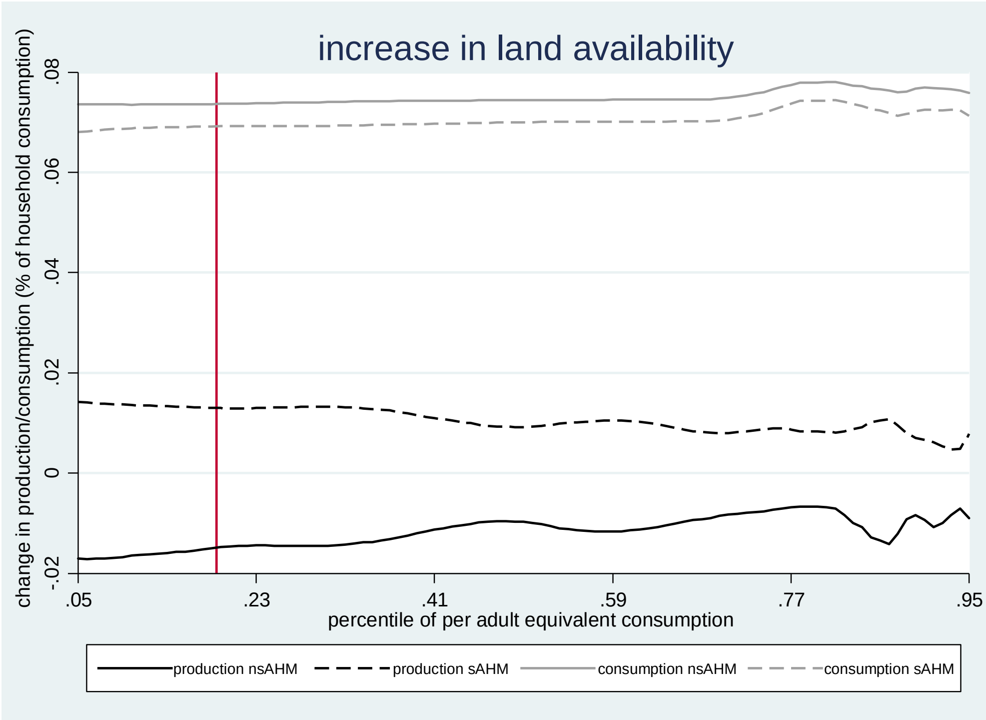
Figure 2. *Poverty (FGT0 and FGT1) curves – non-farmers*

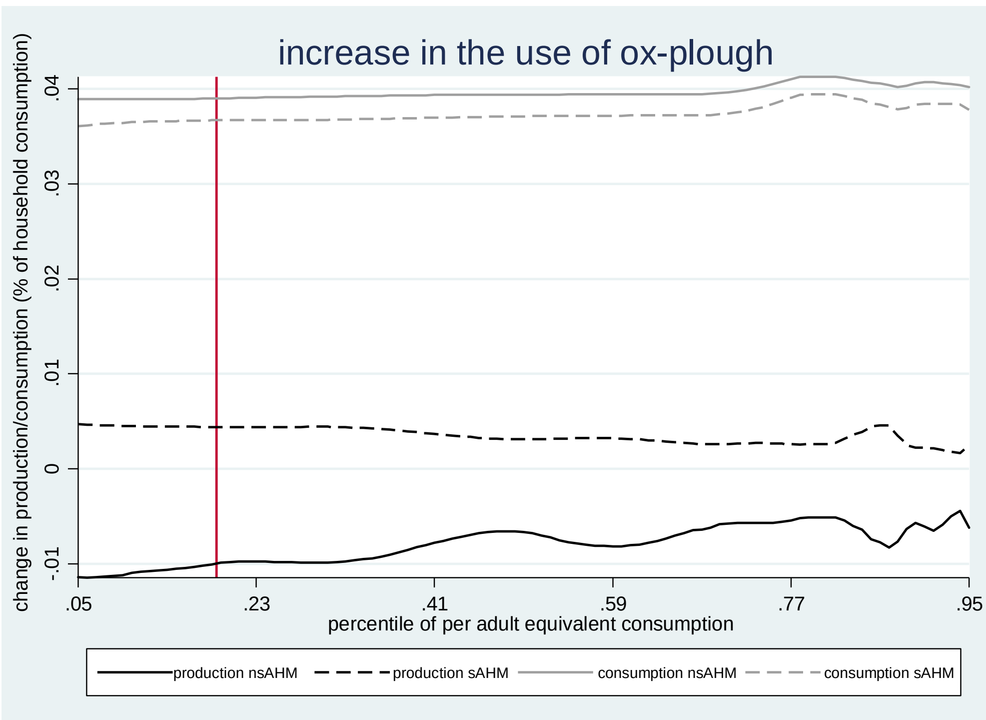


Note: Poverty line is normalized to 100. The graphs are drawn with DASP (Araar and Duclos, 2007).
Source: Authors' estimations using TNPS-1 (see GoT, 2010).

Figure 3. Variation in production and consumption under non-separable (ns) and separable (s) AHM, only farmers

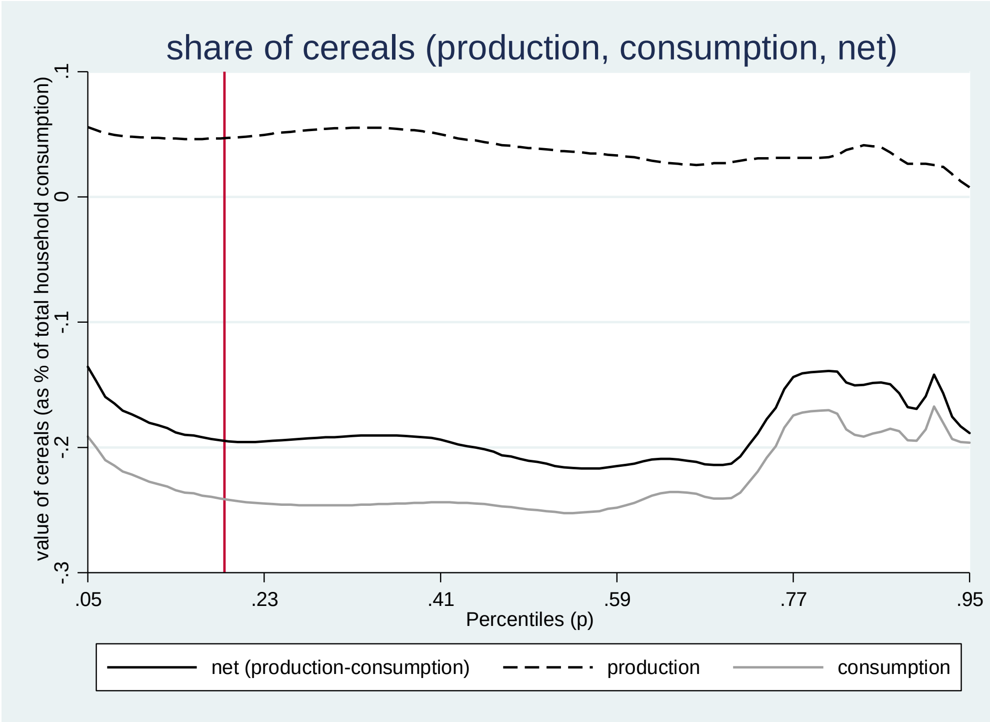






Note: The vertical line identifies the percentile lying on the poverty line. The graphs are drawn with DASP (Araar and Duclos, 2007).
Source: Authors' estimations using TNPS-1 (see GoT, 2010).

Figure 4. Value of cereals (production, consumption and net consumption) as share of total household consumption, farmers



Note: The vertical line identifies the percentile lying on the poverty line; as an increase in the price of cereals affects consumption negatively and production positively, the consumption-related curve is below the zero line and the production-related curve is above the zero line. The net consumption curve is simply obtained by difference between production and consumption. The graphs are drawn with DASP (Araar and Duclos, 2007).
Source: Authors' estimations using TNPS-1 (see GoT, 2010).