The Impact of Agricultural Policy on Rural Households in Tanzania: An Assessment of Consumption, Production and Welfare Effects Through an Agricultural Household Model

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The objective of this study is to assess the impact on poverty and inequality reduction of different policies aiming at increasing agricultural production in Tanzania, by implementing a non-separable agricultural household model. In particular, we concentrate on labour market failure, since in our opinion this is among the major constraints in a context like that of rural Tanzania. Non-separability implies that production and consumption decisions are interlinked and that labour allocation is likely to be determined by shadow wages rather than market wages. Thus, a two-stage estimation strategy is adopted: first the shadow prices of family labour is estimated and then used to estimate the production and demand systems by means of a multi-input multi-output production system and a complete demand system. After the estimation of the production-consumption model, the impact of a number of policies on monetary poverty and inequality is estimated. In particular, the impact of the policies established by the Agricultural Sector Development Programme is evaluated in this analysis, as well as changes in food prices.

Keywords: agricultural household models, poverty, inequality, agricultural policies.
JEL: D12, O12, O13, Q12, Q18

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1 – Introduction and motivation of the study

The role of agriculture in economic development is a *topos* of the development debate since the early stages of the development thought. In those years authors like Johnston and Mellor (1961) and Kuznets (1964) emphasized the importance of the contribution of agriculture to economic development in terms of production, market, resource and foreign exchange. However, even in those years other authors, like Rosenstein-Rodan (1943) and Hirshman (1958), advocated industry-based development strategies emphasizing the low growth potential of agriculture because of its alleged low multiplier effect.

Later on, Timmer (1988) convincingly argued in favour of a positive role of agriculture in economic development, emphasizing that agriculture changes its role according to the stages of development and that ignoring agricultural growth in early stages of development – i.e. implementing the so-called "jump strategies" – is generally bound to failure.

More recently, another argument has been brought about to support agricultural growth, that is agriculture-based growth is more effective than non-agricultural-based growth in reducing poverty[1] as shown by Ravallion and Datt (1996), Christiaensen and Demery (2007) and Ligon and Sadoulet (2007). The assumption behind this is that agricultural growth is generally pro-poor, that is it benefits lower deciles in the income distribution proportionally more than higher deciles.

In addition, many studies showed that farm productivity improvements may also generate positive trickling-down effects on non-farm activities in rural areas (Adelmann, 1984; Hazell and Haggblade, 1991; Haggblade *et al*., 2007). Such non-farm activities are crucial in avoiding that rural households fall below the poverty line. This implies that agricultural growth can reduce poverty not only through its direct effects on farm employment generation or agricultural income growth, but also through its indirect (or linkages) effects on output growth in labour-intensive non-farm activities such as food and beverages industry (Mellor, 2000)[2]. The policy implication is that agricultural development cannot be dismissed in any poverty alleviation strategy[3] and this is particularly true in countries still dominated by rural economy.

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[1] Although some authors (see, for example, Dorward *et al.*, 2004) argue that reliance on pro-poor agricultural growth as the main tool to fight rural poverty currently faces more difficult challenges than during the green revolution years, due to a number of limiting factors such as less productive and more risky agro-ecological conditions and technologies, greater competition in output markets, lower stocks of and/or access to physical and financial capital, etc.

[2] As argued by Anriquez and Stamoulis (2007) agricultural growth may help poverty alleviation 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 (being agriculture typically intensive in unskilled labour).

[3] It seems clear that agriculture relates to nearly all the Millennium Development Goals (MDGs) and is central to at least three of them – i.e. reducing poverty and hunger, fostering gender equality, and sustainable management of the environment.

Building on this literature, this dissertation analyzes the potential impacts of agricultural growth in fighting poverty focusing on the first channel emphasized above, that is the direct contribution to poverty alleviation through the increase of household income and own consumption, with an empirical application to Tanzanian farmers. The choice of Tanzania as case study was made purposely. In fact, Tanzania is still one of the poorest countries in the world and, although Tanzanian economy has grown rapidly since the end of '90s with GDP growing at 6.6 percent per year between 1998 and 2007, household income poverty has remained virtually unchanged both in rural and urban areas, falling only 2.1 percentage points from 35.7 percent in 2000–2001 to 33.6 percent in 2007 (World Bank, 2011). Moreover, the share of the population with insufficient calorie consumption declined only marginally from approximately 25.0 to 23.5 percent over the same period and the rate of child stunting remained nearly unchanged at about 40 percent between 2001 and 2007.

Tanzania economy is still dominated by agriculture, specifically small-scale farming. Aggregate agricultural output has grown sensibly since the end of '90s. However, a closer examination of data shows that agricultural growth was driven by large-scale farmers and growth was very uneven, affecting only a few regions of the country (Pauw and Thurlow, 2010). Therefore, it can be argued that the current structure of agricultural growth, which favours large-scale producers of rice, wheat, and traditional export crops, as well as the slow expansion of food crops and livestock explain the negligible impact of agricultural growth on poverty and nutrition. Indeed, the analysis of recent production trends suggest that although the agricultural sector as a whole grew rapidly during 2000-2007, and the source of this growth has been concentrated among few crops and few regions. Rice and wheat, for example, dominated cereals production trends; cotton, tobacco, and sugar grew at almost 10 percent per year. These crops are concentrated in the North-Eastern part of the country and are more often produced by larger-scale commercial farmers. Thus, while the strong expansion of aggregate agricultural output in recent years may suggests that agricultural growth in Tanzania is broad based, a closer examination of data suggests quite the opposite. Moreover, agricultural growth was insufficient to make a significant difference in per capita incomes and rural poverty. Indeed, despite the overall positive performance, Tanzania's recent agricultural growth is not sufficient to meet the ambitious goals of the national poverty reduction strategy[4].

During the '90s the Tanzanian government paid only modest attention to sectoral policies, focusing primarily on macro policies to provide a thrust towards a free market economy (Wobst and

[4] With an average annual rate of 3.5 percent, Tanzania's agricultural growth exceeds the Sub-Saharan African average of 3.3 percent. However, with a population growth rate of 2.9 percent during the 1990s it was not enough to determine a sustained growth in rural per capita incomes (Gordon, 2008).

Mhamba, 2010). Vice versa, it has recently recognized the pivotal role of agriculture in reducing poverty. Agricultural sector development is currently at a critical stage as new initiatives[5] have been implemented. In particular, the Agricultural Sector Development Programme (ASDP), launched in 2006, is the operational program that implements 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 (GoT, 2011).

Hence, Tanzania seems to be a good case study to assess the effectiveness of agricultural policy reform in stimulating agricultural growth and reducing poverty through the analysis of farmers' production and consumption behaviour and the assessment of policy impacts on households' welfare. The main objective of this study is to provide an answer to the following research question: which government intervention aiming at increasing agricultural production is most effective at achieving national poverty objectives? The justification of this research is primarily empirical: it aims at developing a model to measure how changes in agricultural production affect households in terms of poverty and income inequality[6]. Given that the bulk of the poor lives in rural areas and earns most of its income from agriculture[7], effective agricultural policies are critical for reducing poverty.

From the theoretical viewpoint, this study is a further contribution to the analysis of farmers behaviour, and in particular of production and consumption decisions with missing markets, which call for a non-separable agricultural household modelling strategy[8] (Singh *et al.*, 1986; de Janvry *et al.*, 1991)[9]. In particular, we concentrated on labour market failure, since in our opinion this is among the major constraints in a context like that of rural Tanzania, where labour is the most important input in farm production. Non-separability (due to an imperfect labour market) implies not only that production and consumption decisions are interlinked, but also that labour allocation is likely to be determined by shadow wages rather than market wages. In order to capture this feature, a two-stage estimation strategy has been adopted: first the shadow prices of family labour has been estimated and then used to estimate the production and demand systems by means of a multi-input multi-output production system (*translog*) and a complete demand system (AIDS). The production

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[5] Such as the Kilimo Kwanza, the Southern Agricultural Growth Corridor of Tanzania (SAGCOT), and the Comprehensive Africa Agriculture Development Programme (CAADP)

[6] This research is part of a larger study. The micro-simulations of agricultural policies on households' welfare carried out in this study will feed into a dynamic computable general equilibrium model to predict the effectiveness of agricultural policies and, in particular, alternative land reforms in Tanzania.

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

[8] As known, a separable agricultural household model rests on the assumption that hired labour and family labour are perfect substitutes and that labour market works perfectly.

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

and consumption decisions taken under labour market failures are thus interlinked through the family labour (which enters in the production system) and its counterpart in the consumption system, which is leisure; both prices are determined by the shadow wage as estimated in the first stage. The models above are able to capture adjustments in production (both in output and input) and consumption patterns resulting from specific policy interventions whose impacts are mimicked through simulations.

The study is organized as follows. Chapter 2 explains the estimation strategy and the empirical specification of the agricultural household model, and presents the estimates of the production and demand systems[10] and of the related elasticities. In Chapter 3 a number of micro-simulations of the impact of price changes and of policies aiming at increasing farm production on monetary poverty and income inequality are carried out[11]. The change in the profit from the agricultural sector (as a result of these policies and price changes) is then plugged into the demand model, thus generating the new consumption vectors (in real terms) are generated. Results of these micro-simulations will be used to draw possible policy implications in terms of poverty reduction.

Chapter 4 summarizes the main findings of the study and the policy implications.

2. Estimation of Agricultural Household Model

2.1. Theoretical model

In this section we build a static model to estimate households' production and consumption responses when labour markets fail[12]. This is the case of Tanzanian rural economy, which calls for a non-separable agricultural household modelling strategy.

The farm household is assumed to maximize utility subject to technology, budget and market constraints. The utility function to be maximized can be represented as follows:

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[10] The study will use data from the 2008/2009 Year One National Panel Survey Integrated Households Survey (TNPS-1), implemented by Tanzania National Bureau of Statistics (GoT, 2010) from October 2008 to September 2009.

[11] In particular, the policies assessed in this study are: the increase of the proportion of households using improved technologies (improved seeds) to 35 percent and irrigation to 20 percent; the increase of the proportion of households using mechanization (ox-ploughs) to 30 percent; the increase of the percentage of farmers having access to crop extension services to 55 percent. In addition, some price changes are simulated (i.e., a 20 percent subsidy to fertilizers' price, the effect of the increase in the price of food commodities from May 2007 to September 2009, the impact of food prices increase between October 2009 and November).

[12] We have focused on labour market failures, because this is one of the major constraints in a context like that of rural Tanzania, where labour is the most important input in farm production. Focusing only on labour market failures, we have disregarded other important constraints (above all, credit constraints, cf. Feder *et al*., 1990; Iqbal, 1981), as well as other aspects of farmers' decisions like price and production risk (Fafchamps, 1992), which are difficult to catch in a single-period analysis.

$$U(c_m, c_a, T - l_s; D, R) \qquad (1)$$

where c_m and c_a represent non-agricultural and agricultural consumption goods, respectively; T is total time household available, l_s is total household labour supply and, thus, T- l_s is leisure; l_d is on-farm labour requirements; D represents household characteristics, and R household's resource endowment.

The constraints to the maximization problem are:

$$q_a = q_a(l_d, x; Z) \qquad (2)$$

$$p_m c_m + p_a c_a = wl_s + (p_a c_a - wl_d) + K \qquad (3)$$

$$c_a - q_a >=< 0 \qquad (4)$$

$$l_d - l_s \geq 0 \qquad (5)$$

$$c_m \geq 0; T - l_s \geq 0; l_s \geq 0; l_d \geq 0; c_a \geq 0 \qquad (6)$$

Equation (2) formalizes the production technology, represented by a multi-input multi-output production function, where q_a is a vector of agricultural goods produced by the farm household, which uses variable intermediate inputs (x), labour (l_d), and land as quasi-fixed factor (Z). Equation (3) is the budget constraint where p_m is the price of non-agricultural (manufactured) goods; p_a is the price of agricultural products; w is the agricultural wage; l_s is household labour supply; and K represents all non-farm income. In short, total consumption (i.e. the left hand side of equation (3) cannot exceed total household income (i.e. the right hand side of equation (3)).

Equation (4) represents the market environment constraints for quantities of agricultural goods produced and consumed: households are either net buyers (when $c_a > q_a$) or self-sufficient (when $c_a = q_a$) or net-sellers of agricultural goods (when $c_a < q_a$).

Equation (5), instead, represents the market environment constraints for agricultural labour. When the strict inequality holds the household hires labour, when equality holds households are self-sufficient in labour for farm production.

Equation (6) imposes the usual non-negativity constraints for consumption of food and non-food goods, leisure, and demand for and supply of labour.

If non-separability holds (e.g. due to an imperfect labour market), this implies not only the interaction of production and consumption choices, but also that labour allocation is likely to be endogenously determined by the shadow wage rate rather than the market equilibrium wage rate.

2.2. Empirical Specification[13]

Following the empirical approach proposed by Henning and Henningsen (2007a and 2007b), a non-separable agricultural household model has been estimated using the 2008/2009 Tanzania National Panel Survey Integrated Households Survey (TNPS-1) data.

A two-stage estimation strategy has been adopted, estimating first the shadow prices of family labour through production function modelling and then estimating supply and demand functions through the inclusion of the shadow wage rates into a multi-input multi-output production system (*translog*) and a complete demand system (AIDS), respectively. The production and consumption decisions made when labour market fails are thus interlinked by the family labour (which enters in the production system) and its counterpart in the consumption system, i.e. leisure, setting both prices at the shadow wage level as estimated in the first stage.

This modeling strategy makes possible an assessment of the adjustments in production (both in output and input) and consumption patterns as a result of changes in specific decision variables.

In order to estimate the shadow wage of household labour we have followed Jacoby (1993) and Abdulai and Regmi (2000). The Cobb-Douglas functional form has been used, despite its limitations, because of its easiness of estimation and interpretation.

In order to assess the level of and interactions among different farm products resulting from the implementation of alternative agricultural and price policies, we estimated output supply and input demand elasticities by 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 the methodology proposed, among others, by Ball (1988) and Fulginiti and Perrin (1990).

On the consumption side, an Almost Ideal Demand System (AIDS) proposed by Deaton and Muellbauer (1980) has been used to estimate the impact of changes in prices and income on households' consumption behaviour.

2.3. Households' Production and Consumption Behaviour: Estimation Results[14]

2.3.1. Shadow wage estimation

The OLS and IV estimates of the Cobb-Douglas production function are reported in table 1.

The OLS regression displays a very high determination coefficient ($R^2 = 0.5082$) and most of the estimated coefficients have the expected signs.

[13] A detailed description of empirical specification and estimation strategy is reported in Annex 1.
[14] In Annex 3 there are definitions, means and standard deviations of all variables used in main empirical specifications.

Most inputs have significantly positive effects on agricultural output. Land is the most important input in the production process. All labour typologies but child labour have impacts significantly different from zero. The coefficients for the labour variables show that using family labour has more or less the same impact on agricultural output than hired labour, not supporting the hypothesis that family members have stronger work incentives compared to hired labour. Moreover, while the impact of hired female labour is greater than that of male hired labour, in the case of family labour the impact is reversed[15]. This is probably due to the fact that the activities such as ploughing, which are undertaken by men, contribute more marginally to output than activities such as weeding and transplanting in which females are largely engaged in Tanzania. Land quality and mechanization have a significantly positive effect on farm production.

The only inputs that do not have a significant impact on production are pesticides, organic fertilizers and irrigation. Also the household head's schooling does not have a significant impact on agricultural output, not supporting the widely accepted role of human capital in improving farmers' production. Infrastructures such as roads and markets do not have statistically significant effects on production.

However, the physical inputs are likely to be endogenous. Therefore, instrumental variables (IV) are included in order to estimate the production function[16]. The tests for endogeneity suggest that the OLS model is rejected by both the Durbin test and the Wu-Hausman test, which indicate the need for an IV procedure. Moreover, the Sargan test rejects the hypothesis that excluded instruments are valid instruments, i.e., uncorrelated with the error term and correctly excluded from the estimated equation.

[15] This result is consistent with the findings of Abdulai and Regmi (2000), but contrasts earlier findings by Skoufias (1994) who found that in India family female labour showed a greater impact on output than family male labour.

[16] Set of instruments used in the production function analysis:
- Household composition variables: number of children (aged<15), number of elderlies (aged>60), number of female adults (aged>14 and <61), number of male adults (aged>14 and <61);
- District level prices and wages: price of maize (logarithm), adult farm daily wage;
- Dwelling characteristics: home ownership dummy (1 if own, 0 otherwise), cooking fuel dummy (1 if electricity or gas, 0 otherwise), source of drinking water dummy (1 if piped water inside or outside dwelling, 0 otherwise).

Table 1

Production function estimates

Dependent variable: loutput_value Independent variables	OLS Coef.	OLS Std. Err.	IV Coef.	IV Std. Err.
lhh_pesticides[a]	0.063	0.044	-1.982*	0.044
lhh_inorganic_fert[a]	0.163***	0.021	0.023	0.021
lhh_organic_fert[a]	0.017	0.015	0.204	0.015
lhired_female[a]	0.132***	0.023	0.242	0.023
lhired_male[a]	0.062**	0.025	0.395	0.025
lhh_land	0.477***	0.051	0.613***	0.038
lhh_tot_lab_f	0.069***	0.022	0.114**	0.022
lhh_tot_lab_m	0.110***	0.024	0.142***	0.024
lhh_tot_lab_child	0.011	0.016	0.024	0.016
hh_head_age	-0.002	0.010	-0.001	0.010
hhhead_age^2	0.000	0.000	0.000	0.000
hh_head_sex	-0.157*	0.092	-0.122	0.092
literate	0.068	0.073	0.044	0.073
land_quality	0.374***	0.051	0.436***	0.052
irrigation	0.309	0.237	1.243	0.213
lroad	0.014	0.050	0.026	0.026
lmarket	-0.019	0.032	-0.095	0.032
lmechanization	0.060***	0.013	0.046	0.013
cons	8.973***	0.286	8.452***	0.294
R^2 50.82				
		IV test results		
		Durban[b]: chi-sq(5)=10.3		p=0.06
		Wu-Hausman[b]: F(5,1832)=2.06		p=0.07
		Sargan test[c]: chi-sq(4)=6.90		p=0.14

Notes: * significant at 90 percent; ** significant at 95 percent; *** significant at 99 percent.

[a] Variables considered endogenous in the instrumental variable estimation.

[b] The Durban test and the Wu-Hausman test determine whether endogenous regressors in the model are in fact exogenous.

[c] The Sargan test is a test of over-identifying restrictions. The joint null hypothesis is that the instruments are valid instruments, i.e. uncorrelated with the error term, and that the excluded instruments are correctly excluded from the estimated equation.

Source: Authors' calculations from TNPS-1

Table 2 reports the estimates of the household shadow wages obtained using equation (A.11) The F-statistics show that the null hypothesis of equality between the marginal product and market wage rates can be rejected for the whole sample and for both urban and rural workers[17]. In addition, t test shows that the difference between the means of shadow and market wages is significant at 99 percent. This finding supports the hypothesis of an interdependence of production and consumption decisions by the agricultural households and justify the use of a non-separable model.

[17] This finding supports earlier results by Jacoby (1993), Skoufias (1994) and Abdulai and Regmi (2000).

Table 2

Tests of the equality of wages and estimated marginal product

Tests of the market wages and estimated marginal products				
	a'	**b'**	**R^2**	**F-test***
All	304.20 (20.97)	0.0014 (0.0085)	0.0009	0.03
Rural (*n*=1699)	370.89 (16.24)	-0.0393 (0.0068)	0.02	33.27
Urban (*n*=238)	-138.79 (148.46)	0.2151 (0.0482)	0.08	19.89
Two-sample t test with unequal variances				
	Difference	Std. Err.		t-test**
All	1951.30	(27.48)		71.00
Rural	1930.02	(27.76)		69.53
Urban	2103.24	(100.20)		20.99

Standard errors in parentheses.
* Null hypothesis: (a, b)=(0, 1)
** Null hypothesis: difference (mean[mkt wage] – mean[shadow wage])=0

Source: Authors' calculations from TNPS-1

2.3.2. Production

The *translog* production system based estimates of output shares (cf. equation (A.6)) as well as the profit function (equation (A.4)) are reported in Table 3. Share functions refer to maize, other cereals, fertilizers and pesticides, household labour and hired labour (all these shares sum to one), while the other crops share is estimated by difference. Furthermore, two fixed input (*Z*) are included in the system: Z_1 is the area-weighted average number of irrigations; Z_2 is the land input measured as hectares cultivated by farms in the long rainy season 2008/2009[18]. Finally, the profit function includes also other variables[19] – such as the use of improved seeds, the ownership of an ox-plough, the household head's education status (literate or not) and access to extension services – in order to capture the effect of these other factors on production.[20]

The econometric performance of this model is quite good considering that duality-based estimations using microeconomic data are usually less performing vis-à-vis estimations based on aggregate data.

All own-price coefficients, except the one of fertilizers and pesticides, have the expected signs and are significantly different from zero, except maize. This means that the output supply and factor

[18] In several empirical works land and irrigation are introduced in production system as fixed inputs (see Sidhu and Baanante, 1981; Bapna, *et al*., 1984; Evenson, 1983).
[19] These variables have been included as dummies because of data limitations. As a result, they appear in the profit function only, since they are not interrelated with prices (see, for example, Olson and Zoubi, 2001).
[20] Infrastructural variables, like distance to road or the presence of a market in the village, were not statistically significant in any specification. Therefore, they have been dropped.

demand equations are consistent with underlying profit maximization theory. Maize and other cereals are product substitutes, since the estimated parameter (LnP_1LnP_2) is negative. Instead, irrigation and land are complements, since the estimated parameter (LnZ_1LnZ_2) is positive.

Land is statistically significant in all share functions, as well as in profit function. Specifically, it is positive for output shares and profit functions and negative for input function shares. Irrigation shows a substitution effect with other inputs (fertilizers and pesticides), a significant and very high effect on household labour, and a positive and significant effect on profit. All dummy variables (i.e. improved seeds, ox-plough, household head educational attainment and extension services) have the expected signs and are significant at 99 percent (except extension services, significant at 95 percent).

Table 3

Restricted parameters estimates of the *translog* profit function

		Intercept	Price of Maize (LnP_1)	Price of Other cereals (LnP_2)	Price of Fertilizers and pesticides (LnP_3)	Price of Household labour (LnP_4)	Price of Hired labour (LnP_5)	Irrigation (LnZ_1)	Land (LnZ_2)
Share equation of	**Maize - S_1**	0.576**	-0.013	-0.589**	-0.075	0.671***	0.066	0.284	0.370***
		(0.242)	(0.373)	(0.295)	(0.051)	(0.223)	(0.144)	(0.455)	(0.099)
	Other cereals - S_2	-0.165	-0.589**	1.370***	-0.051	-0.302	0.000**	-0.661	0.160*
		(0.195)	(0.295)	(0.282)	(0.052)	(0.213)	(0.000)	(0.428)	(0.086)
	Fertilizers and pesticides - S_3	-0.130*	-0.075	-0.051	0.029*	0.038	0.025	-0.856*	-0.093*
		(0.069)	(0.051)	(0.052)	(0.016)	(0.063)	(0.031)	(0.440)	(0.056)
	household labour - S_4	0.229	0.671***	-0.302	0.038	-0.714***	0.034	1.665**	-1.013***
		(0.302)	(0.223)	(0.213)	(0.063)	(0.217)	(0.125)	(0.743)	(0.130)
	Hired labour - S_5	0.532***	0.066	0.000*	0.025	0.034	-0.194**	0.439	-0.351***
		(0.141)	(0.144)	(0.000)	(0.031)	(0.125)	(0.085)	(0.310)	(0.059)
Profit Function		2.397***	0.544**	-0.193	-0.146**	0.378	0.547***	0.144*	0.776***
		(0.189)	(0.241)	(0.196)	(0.069)	(0.300)	(0.141)	(0.129)	(0.129)
		$(LnP_1)^2/2$	**$(LnP_2)^2/2$**	**$(LnP_3)^2/2$**	**$(LnP_4)^2/2$**	**$(LnP_5)^2/2$**	**LnP_1LnP_2**	**LnP_1LnP_3**	**LnP_1LnP_4**
		0.025	1.428***	0.029*	-0.581**	-0.198**	-0.620**	-0.063	0.601***
		(0.375)	(0.375)	(0.016)	(0.240)	(0.086)	(0.294)	(0.050)	(0.223)
		LnP_1LnP_5	**LnP_2LnP_3**	**LnP_2LnP_4**	**LnP_3LnP_4**	**LnP_3LnP_5**	**LnP_4LnP_5**	**LnP_5LnP_2**	**LnP_1LnZ_1**
		0.078	-0.047	-0.359	0.030	0.022	0.019	0.109*	1.616
		(0.145)	(0.052)	(0.221)	(0.064)	(0.031)	(0.126)	(0.057)	(1.023)
		LnP_1LnZ_2	**LnP_2LnZ_1**	**LnP_2LnZ_2**	**LnP_3LnZ_1**	**LnP_3LnZ_2**	**LnP_4LnZ_1**	**LnP_4LnZ_2**	**LnP_5LnZ_1**
		0.385***	0.384	0.149*	0.404*	0.035	-0.599	0.317***	-0.726
		(0.099)	(0.893)	(0.087)	(0.244)	(0.027)	(0.779)	(0.118)	(0.746)
		LnP_5LnZ_2	**$(LnZ_1)^2/2$**	**$(LnZ_2)^2/2$**	**LnZ_1LnZ_2**	**improved**	**ox**	**literate**	**extension**
		-0.136**	-0.118***	-0.118***	0.118***	0.207***	0.469***	0.198***	0.142**
		(0.064)	(0.043)	(0.043)	(0.043)	(0.070)	(0.094)	(0.063)	(0.065)

Standard error in parenthesis

*** Significant at 0.01 level; ** Significant at 0.05 level; * Significant at 0.10 level

Source: Authors' calculations from TNPS-1

The parameters explain the influence of output and variable input prices and fixed inputs on the mix of shares of different crop outputs and inputs. However, in order to study the responsiveness of crop supply and input demand and to evaluate the effects of policies on the levels of outputs and inputs, elasticities need to be estimated.

The full set of price elasticities for output supply and input demand have been computed using sample means, according to equations (A.7) and (A.8) (Table 4). Maize has the lowest own-price elasticity, confirming that maize is grown as a subsistence self-consumed crop, weakly responsive to price changes. Since the own-price elasticities of other cereals and other crops categories are greater then one, the supply response is expected to be larger for other crops producers than for maize producers.

All the cross-supply elasticities are positive, revealing complementary relationships 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, as a commodity price rises, new inputs are drawn into general production leading to an increase in the production of other products as well. Moreover, this indicates a low potential for diversification in Tanzanian agriculture.

Own and cross-price input demand elasticities are generally higher than supply elasticities, revealing a significant price responsiveness by Tanzanian producers in using inputs. Moreover, all cross-price elasticities for inputs are negative, which means that inputs are complements: an increase in one input price, keeping the output prices constant, tend to reduce the demand for other inputs. Similar results are reported in Fulginiti and Perrin (1990), Antle and Aitah (1986), Ball (1988), Govindan and Babu (1996). The negative elasticity of the labour demand to household shadow wage, market wage and fertilizer price shows that their combined application increases farm production synergistically. Moreover, the higher cross-price elasticity of fertilizer demand with respect to shadow and market wages than the elasticity of demand of household labour with respect to the price of fertilizer explains the labour intensive production system of Tanzanian agriculture.

Cross-elasticities of output supply to input prices are always negative: this is consistent with the economic theory. In particular, the size of output elasticities to input prices shows that production is very responsive to household labour, an expected result in the context of Tanzanian rural economy.

Table 4

Output and input price elasticity matrix

Quantity of	Price of					
	Maize	**Other cereals**	**Other inputs**	**Household labour**	**Hired labour**	**Other crops**
Maize	0.358	0.247	-0.681	-1.362	-0.485	1.383
Other cereals	0.465	1.723	-0.700	-2.317	-0.543	0.831
Other inputs	1.438	0.783	-1.680	-1.859	-0.579	1.356
Household labour	1.007	0.907	-0.651	-2.490	-0.554	1.240
Hired labour	1.196	0.709	-0.676	-1.847	-1.178	1.255
Other crops	0.935	0.559	-0.510	-1.875	-0.878	1.228

Source: Authors' calculations from TNPS-1

2.3.3. Cosumption

Table 5 shows that most of the estimated parameters of the AIDS demand system[21] are highly significant. Among demographic variables, household size significantly influences the expenditure share of most food groups, while the number of children has an impact only on the consumption share of vegetables and fruits as well as meat, eggs and dairy. The household size coefficient is positive and significant for non-essential items (beverages, sugar and sweets), but negative and highly significant for maize, starches, pulses, dry, nuts and seeds, vegetables and fruits, fish and salt and spices.

The sign of own price and income (expenditure) elasticities, reported in Table 6, are consistent with theory and their magnitudes are within the expected range[22]. Other cereals, meat, eggs and diary, fish (and leisure) consumption is very sensitive to own price changes.

The food expenditure elasticities to income are positive for all commodity groups, except pulses and dry nuts, indicating that consumption will increase with increased incomes. Maize, the most common consumed item, has the lower positive expenditure elasticity. Meat, eggs, milk and milk products, vegetables and fruits, other cereals, sugar and sweets, oil and fats and beverages (the highest value) have expenditure elasticities above one, indicating that these commodities are superior goods.

These findings suggest that as income increases consumers tend to spend proportionately less on maize, pulses and fish, and more on meat, eggs, dairy products, beverages, as well as other foods.

[21] As noted on footnote 49 only poverty estimates based on food expenditure are in line with alternative poverty available for Tanzania. Thus, the demand system was estimated for food expenditure only, in order to obtain "reliable" estimates of the real equivalent income.

[22] Although food categories are different, expenditure elasticities are comparable to those reported by Abdulai and Aubert (2004), which carry out a QUAIDS demand system, for Tanzania.

Table 5

AIDS demand system estimates

		Price of													
Share equation of	Intercept	Maize (LnP_1)	Other cereals (LnP_2)	Starches (LnP_3)	Sugar and sweets (LnP_4)	Pulses and seeds (LnP_5)	Vegetables and fruits (LnP_6)	Meat, eggs, diary (LnP_7)	Fish (LnP_8)	Oil and fats (LnP_9)	Salt and spices (LnP_{10})	Beverages (LnP_{11})	children_n	ln_hhsize	ln_y_equiv
Maize S_1	-0.296*** (0.071)	0.008 (0.005)	0.029*** (0.004)	-0.012*** (0.004)	0.005*** (0.002)	-0.000 (0.003)	-0.008** (0.003)	-0.017*** (0.004)	0.018*** (0.002)	-0.004** (0.002)	0.000 (0.000)	0.030*** (0.005)	0.000 (0.002)	-0.031*** (0.009)	-0.094*** (0.015)
Other cereals S_2	0.371** (0.162)	0.029*** (0.004)	-0.117*** (0.015)	-0.008 (0.008)	-0.019*** (0.005)	0.034*** (0.008)	0.036*** (0.007)	0.038*** (0.010)	-0.012** (0.006)	0.003 (0.005)	0.000 (0.001)	-0.021*** (0.004)	0.000 (0.001)	0.014* (0.008)	-0.034** (0.014)
Starches S_3	1.036*** (0.094)	-0.012*** (0.004)	-0.008 (0.007)	0.003 (0.008)	-0.004 (0.003)	-0.015*** (0.006)	-0.042*** (0.005)	0.000 (0.007)	-0.011*** (0.004)	-0.016*** (0.003)	-0.001* (0.001)	-0.032*** (0.004)	0.001 (0.002)	-0.022*** (0.008)	-0.060*** (0.014)
Sugar and sweets S_4	0.066 (0.067)	-0.005*** (0.002)	-0.019*** (0.005)	-0.004 (0.003)	0.010*** (0.004)	0.009** (0.004)	-0.004 (0.003)	0.009** (0.004)	-0.009*** (0.003)	0.003 (0.003)	-0.003*** (0.001)	-0.004*** (0.001)	0.000 (0.001)	0.005** (0.003)	0.019*** (0.005)
Pulses and seeds S_5	-0.386*** (0.116)	0.000 (0.003)	0.034*** (0.008)	-0.015*** (0.006)	-0.009** (0.004)	0.036*** (0.009)	-0.018*** (0.006)	0.036*** (0.008)	0.010** (0.005)	-0.003 (0.004)	-0.001 (0.001)	-0.016*** (0.003)	0.000 (0.001)	-0.031*** (0.006)	-0.070*** (0.011)
Vegetables and fruits S_6	-0.099 (0.095)	-0.008** (0.003)	0.036*** (0.007)	-0.042*** (0.005)	-0.004 (0.003)	-0.018*** (0.006)	0.030*** (0.007)	-0.006 (0.007)	0.033*** (0.004)	-0.002 (0.003)	0.000 (0.001)	0.005 (0.003)	0.003** (0.001)	-0.031*** (0.006)	0.016 (0.010)
Meat, eggs, diary S_7	-0.152 (0.136)	0.017*** (0.004)	-0.038*** (0.010)	0.000 (0.007)	0.009** (0.004)	0.036*** (0.008)	-0.006 (0.007)	-0.065*** (0.012)	0.029*** (0.005)	-0.003*** (0.004)	-0.002*** (0.001)	-0.001*** (0.004)	0.010*** (0.001)	0.012 (0.007)	0.105*** (0.013)
Fish S_8	-0.072 (0.077)	0.018*** (0.002)	-0.012** (0.006)	-0.011*** (0.004)	-0.009*** (0.003)	0.010** (0.005)	0.033*** (0.004)	0.029*** (0.004)	-0.024*** (0.004)	-0.003 (0.003)	-0.002** (0.001)	-0.003* (0.001)	0.000 (0.001)	-0.017*** (0.004)	-0.030*** (0.007)
Oil and fats S_9	0.065 (0.071)	-0.004** (0.002)	0.003 (0.005)	-0.016*** (0.003)	0.003 (0.003)	-0.003 (0.004)	-0.002 (0.003)	-0.003 (0.004)	-0.003*** (0.003)	0.007* (0.004)	0.000 (0.001)	0.004** (0.002)	0.000 (0.001)	0.007** (0.003)	0.040*** (0.006)
Salt and spices S_{10}	0.054*** (0.020)	0.000 (0.000)	0.000 (0.001)	-0.001* (0.001)	-0.003*** (0.001)	0.001 (0.001)	0.000 (0.001)	-0.002 (0.001)	-0.002*** (0.001)	0.000 (0.001)	0.001* (0.001)	0.001** (0.000)	0.000 (0.000)	-0.003*** (0.001)	-0.003*** (0.001)
Beverages S_{11}	0.280*** (0.055)	-0.008*** (0.003)	-0.021*** (0.004)	-0.032*** (0.004)	-0.004*** (0.001)	-0.016*** (0.003)	0.005 (0.003)	-0.001 (0.004)	-0.003* (0.002)	0.004** (0.002)	0.001*** (0.000)	0.022*** (0.003)	0.000 (0.001)	0.017*** (0.005)	0.092*** (0.009)

Standard error in parenthesis

*** Significant at 0.01 level; ** Significant at 0.05 level; * Significant at 0.10 level

Household head employment status, household head education status and regions dummies are included in demand system.

Source: Authors’ calculations from TNPS-1

Table 6

Expenditure price and income elasticity matrix

	Price of												
Quantity of	**maize**	**other cereals**	**starches**	**sugar and sweets**	**pulses,dry, nuts and seeds**	**vegetables and fruits**	**meat,eggs and dairy**	**fish**	**oil and fats**	**salt and spices**	**beverages**	**Leisure**	**Income**
maize	-0.818	0.404	0.359	0.081	0.067	0.036	-0.070	0.215	-0.010	0.005	0.361	-0.636	0.006
other cereals	0.264	-2.224	-0.159	-0.207	0.321	0.332	0.348	-0.130	0.024	-0.001	-0.227	0.314	1.344
starches	0.074	-0.007	-0.929	-0.010	-0.045	-0.148	0.027	-0.038	-0.062	-0.004	-0.124	0.519	0.748
sugar and sweets	0.130	-0.810	-0.315	-0.629	0.296	-0.241	0.254	-0.359	0.092	-0.125	-0.186	0.177	1.715
pulses,dry,nuts and seeds	0.106	0.623	0.030	0.166	-0.378	-0.149	0.663	0.193	-0.019	0.024	-0.202	-0.979	-0.076
vegetables and fruits	-0.079	0.299	-0.393	-0.039	-0.163	-0.760	-0.062	0.280	-0.025	-0.004	0.033	-0.227	1.141
meat,eggs and dairy	-0.254	0.262	-0.237	0.056	0.279	-0.171	-1.734	0.250	-0.057	-0.022	-0.052	-0.330	2.011
fish	0.663	-0.286	-0.122	-0.262	0.401	1.192	1.053	-1.741	-0.084	-0.058	-0.070	-0.710	0.024
oil and fats	-0.262	-0.020	-0.907	0.067	-0.205	-0.252	-0.250	-0.164	-0.800	0.009	0.071	0.307	2.407
salt and spices	0.097	0.104	-0.057	-0.655	0.326	0.020	-0.276	-0.378	0.119	-0.767	0.224	1.182	0.059
beverages	-0.399	-0.692	-1.243	-0.150	-0.515	-0.145	-0.243	-0.146	0.026	0.010	-0.592	0.946	3.142
Leisure	-0.208	0.267	0.822	0.058	-0.469	-0.121	-0.088	-0.164	0.106	0.034	0.121	-1.042	0.685

Source: Authors' calculations from TNPS-1

3. Simulation of Agricultural Policies and Price Changes

3.1. Description of agricultural policies and prices variation simulations

The estimated model has been used to assess the impacts on households' welfare of the major changes that took place over the last years in Tanzanian economic environment, namely: the full implementation of phase 1 of the Agricultural Sector Development Program (ASDP) and the change in input and output prices. Given the top-rank priority of the former in Tanzanian Government's objectives, the simulations will focus primarily on the policy reform, applying it to the status quo (baseline) without considering other changes that took place since the model's reference year, i.e. 2008-2009. However, there are changes that cannot be ignored due to their non trivial impacts households' welfare. The most important change is the price fluctuations that took place since the beginning of the food crisis up to now (November 2011): the impacts of those changes have also been simulated as well. Finally, the combined effect of policy reform and policy change has been simulated.

The ASDP is an implementation tool for the Agricultural Sector Development Strategy (ASDS) and the broader National and Global Policies, including the National Strategy for Growth and Reduction of Poverty (most commonly known as MKUKUTA), the Tanzania Development Vision 2025, and the Millennium Development Goals.

Priority actions within the ASDP are increasing the use of modern inputs and technologies (namely, irrigation, improved seeds, erosion control, chemical fertilizers, 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.

In this chapter we will assess the impacts on poverty and inequality of a number of policies included in the Agricultural Sector Development Programme, namely[23] (Table 7): increasing the proportion of farm households using irrigation from 4.49 percent to 20 percent (Simulation 1), increasing the proportion of farm households using improved seeds from 17.91 percent to 35 percent (Simulation 2), increasing the proportion of farm households using mechanization (ox-plough) from 7.49 percent to 30 percent (Simulation 3), increasing the percentage of farmers having access to crop extension services from 22.61 percent to 55 percent (Simulation 4).

The whole package of ASDP measures above has been also simultaneously simulated in Simulation 5: this allows the assessment of how effective the agricultural policies designed by

[23] Other measures included in the ASDP were not simulated since in the production model the variables related to these measures unfortunately were not significant (e.g., variables regarding SACCOs and rural credit, or variables regarding infrastructure as the distance to a market and to a principal road).

Tanzanian Government are and compare their achievements with the outcome targets set by the Agricultural Sector Development Programme (i.e. halving food and monetary poverty).

In addition, we have also simulated an investment in human capital, increasing the percentage of household heads literacy from about 71 percent to about 82 percent (Simulation 6). Simulation 7 combines the complete ASDP package of measures simulated (Simulation 5) with the investment in human capital (Simulation 6).

In order to assess different impacts of these policies on poverty and inequality, four different targeting profiles have been hypothesized[24]. They can be grouped in two categories. The first category is based on the distribution of income across households and compares a targeting oriented to the poorest groups of population[25] ("pro-poor"), versus a policy implementation oriented to those who have the highest probability[26] of being directly interested by the policies ("no targeting"). The second group identifies two targeting profiles according to land size: one oriented to "smallholders" and one oriented to farmers owning relatively more land ("not smallholders")[27].

Another set of simulations refers to changes in the price of inputs and outputs. In particular, a 20 percent reduction in fertilizers' price has been simulated (Simulation 8)[28]. The impact of the increase in cereals prices occurred over the last years has been assessed in Simulation 9[29]. According to existing data[30], Tanzania hit the lowest cereals prices in May 2007; in September 2009 (which is also the last month of our dataset), instead, cereals prices peaked at their highest value (already reached in February 2008). Therefore we considered the price changes that took place

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[24] A limitation in our approach is that we considering only policy impacts, while there are important implementation issues related for instance to the implementation costs that we do not take into account. For example a pro-poor targeting will probably be more expensive than a random policy implementation. This must be taken into account in assessing the performances of different targeting profiles.

[25] The simulated policies are targeted to the poorest quintiles of population, with the highest agricultural profit/income ratio, progressively including households with higher income from the poorest in the sample up to the ranking position where the policy-specific target has been achieved.

[26] For this purpose we have estimated probit and tobit models with the variables to be simulated (i.e. irrigation, improved seeds, ox-plough, extension services and literacy) as endogenous variables. In this case, households have been selected according to these binomial models, starting from the household showing the highest probability and including households with lower probability up to the ranking position where the policy-specific target has been achieved.

[27] It would be misleading to define these farmers as "large farmers". Indeed, those are farmers who cultivate on average less than 5 ha of land.

[28] In 2008 the Tanzanian Government launched a voucher-based fertilizer subsidies program, according to which farmers receive vouchers for 100 kg of fertilizers, other agrochemicals and seeds, redeemable at any private agro-input dealer (Minot and Benson, 2009). Thus, this simulation mimics the effect of this program on the prices of fertilizers and pesticides.

[29] For both the production system and the demand system, we have taken into account the price of rice as a proxy of the price of the category "other cereals", which enters both in the production and demand system. Given the lack of regional data, we have considered data referring to Dar es Salaam only. We are aware that this may entail overestimating the effect of price increase. Moreover, we have hypothesized that consumption prices are equal to production prices, which is quite a strong assumption.

[30] Cereals prices data are from FAO/Global Information and Early Warning System on Food and Agriculture (GIEWS) online dataset (FAO, 2011).

between May 2007 and September 2009 (i.e. 178 percent)[31] as well as the overall change implied by the food price crisis since its inception. Simulation 10 takes into account the price trend since October 2009 (the month following the end of our questionnaire) to November 2011 (the last month for which data were available).

Finally, Simulation 11 combines the complete ASDP package of measures simulated (Simulation 5) with the price trend considered in Simulation 10. This allows the assessment of the "true" impact of the ASDP policies on poverty and distribution.

Since the increase in prices affects all population quintiles, simulations of price changes (Simulations 8, 9 and 10) have been carried out without any targeting (e.g., pro-poor versus non pro-poor, or smallholders versus not smallholders).

3.2. Poverty and inequality estimates[32]

Despite the simulation results are biased because they refer to a full implementation of ASDP policies, they are useful for providing the idea of the direction of change should the ASDP be fully implemented.

These simulations show that, considering single agricultural policies within the ASDP package, mechanization (i.e. ox-plough adoption) is the most effective policy for increasing farm profits and, as a result, reducing poverty[33].

In case of pro-poor targeting, the implementation of the whole ASDP package has a quite strong impact on poverty and inequality reduction (nearly 4.5 and 2 percentage points, respectively, in rural areas). In this case the results referring to poverty reduction are in line with expectations of the Tanzanian government about the impact of ASDP in reducing poverty. The results are even more impressive if the policies are implemented in a more realistic scenario that takes into account the actual changes in food prices since the food price crisis onset (Sim 11).

In case of absence of targeting, ASDP is far less effective in reducing poverty (1.5 percent and 1.15 percent in rural and urban areas, respectively). This suggests that to achieve the poverty reduction objectives of ASDP, the interventions must be addressed to the poorest farm households.

[31] Cereals prices have been deflated by the change in the inflation rate occurred between May 2007 and September 2009.

[32] Poverty and inequality estimates have been carried out by using the DASP program (cf. Araar and Duclos, 2009).

[33] The quite low impact of irrigation (Sim 1) may be explained by the fact that irrigation may be ineffective in mitigating the effects of severe drought as that occurred in Tanzania in 2008/2009. The reason could be that irrigation in Tanzania is mostly gravitational irrigation and, consequently, when droughts are widespread, the rivers dry up, leaving little or no water for irrigation (a similar result can be found in Christiaensen *et al*., 2005).
Surprisingly enough, the provision of extension services (Sim 4) shows a larger impact than the provision of improved seeds in the case of no targeting, while the opposite occurs in case of pro-poor targeting. The same occurs in terms of income distribution.

Of course, there is a trade-off: a more effective poverty reduction implies a higher implementation cost due to targeting.

Finally, the increase in food prices has had a huge impact on households' welfare. The impact on poverty of an increase in cereals prices as the one occurred since the onset of the food price crisis (Sim 9) is quite impressive. Indeed, *ceteris paribus* food prices increase led HCR from 11.52 percent to 16.18 percent. This result may be overestimated, particularly in rural areas (cf. footnote 29). In terms of inequality, the food price jump increased Gini index from 44.94 percent to 46.40 percent (HCR at base run)[34].

This has an immediate policy implication: that is the government should intervene to reduce, although not to eliminate[35], price movements to prevent adverse effects in terms of poverty and income distribution.

The price changes that took place between October 2009 and November 2011 (Sim 10), led to a reduction of 2 percent of the headcount ratio (nearly 2.3 percent in rural areas), and a decrease of 0.7 percent in Gini index.

Considering these price changes along with the ASDP implementation (Sim 11) leads to a further 1.5 percent reduction in headcount ratio estimated without taking account the price changes. The Gini Index decreased by nearly 2.3 percent in the case of pro-poor targeting and nearly 1.2 percent in case of no targeting, a performance better than the one without taking into account the increase in food prices.

Quite surprisingly, a targeting oriented to those who have relatively more land results in a more effective poverty reduction as well as inequality reduction. This is related to the crucial role played by land in farming: land is indeed the limiting factor for smallholders, whose very low land endowment prevents the possibility of increasing agricultural production and profit. Apparently, those endowed with fewer land have greater difficulties in getting out poverty, while targeting policies to those who have relatively more land leads to better results in terms of poverty reduction. ASDP policies are less effective in increasing farm profits of those owing fewer land: the estimation of the production system showed that land is the major input in farm production (cf. section 2.3.2) and it may be that this is the limiting factor in ASDP implementation. Indeed, it is well-known that access to land is a crucial issue in many Sub-Saharan African countries[36] and particularly in

[34] For farm households the increase in food prices had minor effect on poverty, even if, in general, the increase of farm profit following the increase in food prices on the production side did not succeeded in neutralising the reduction of real income following the increase in food prices on the consumption side.

[35] The objective of government intervention should not be the full sterilization of price movements, in order to prevent the signaling functions of prices.

[36] The problem of access to land in Africa has recently become again a hot topic in the development agenda (see, for example, de Janvry and Sadoulet, 2005; Deininger, 2009).

Tanzania, a country abundant in arable land but with a very sticky land market. This calls for a renewed effort in land reform[37].

The better results in terms of inequality reduction in case of policies targeted to those who have relatively more land can be explained by the fact that, increasing incomes of those who have "relatively" more land reduces the distance from those who are "in absolute" wealthier (non-farm households are, in average, 17 percentage points wealthier than farm households), more than increasing incomes of those who have relatively less land (who are poorer and whose farm profit increases less than those more endowed of land). Anyway, in terms of inequality reduction, the difference between the two targeting profiles is negligible (only 0.09 percentage points for all population).

To sum up, this has two main policy implications: (i) there is a need for a new land reform facilitating the access to land for smallholders[38], and (ii) in absence of a land reform, if the policy objectives are the reduction in the overall inequality and poverty, it is better to target relatively larger farmer.

[37] The Tanzanian government has recently reckoned the problem and the Tanzanian Ministry of Lands, Housing and Human Settlement Development is now 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 affected the distribution of land.

[38] It is self-evident that a land reform in the context of Tanzanian agriculture is a win-win option, which improves equality as well as efficiency.

Table 7

Poverty and inequality estimations: pro-poor vs. no targeting

Simulation	Headcount ratio (%)						Gini index (%)					
	Pro-poor			No targeting			Pro-poor			No targeting		
	Urban	Rural	All	Urban	Rural	All	Urban	Rural	All	Urban	Rural	All
Base run	11.826	17.531	16.176	11.826	17.531	16.176	41.084	47.346	46.391	41.084	47.346	46.391
Sim 1	11.826	16.932	15.719	11.826	17.246	15.959	41.067	47.168	46.253	41.081	47.278	46.335
Sim 2	11.826	16.272	15.216	11.826	17.420	16.091	41.037	46.952	46.080	41.082	47.265	46.309
Sim 3	11.826	15.650	14.742	11.826	16.708	15.549	40.926	46.391	45.620	41.023	47.045	46.088
Sim 4	11.826	16.397	15.312	11.826	17.328	16.021	41.038	46.978	46.094	41.063	47.242	46.293
Sim 5	10.806	13.096	12.552	10.806	16.016	15.021	40.745	45.415	44.806	41.014	46.966	45.982
Sim 6	11.826	16.867	15.670	11.826	17.349	16.037	41.071	47.205	46.282	41.064	47.308	46.354
Sim 7	10.806	12.912	12.411	10.806	15.689	14.771	40.719	45.237	44.661	40.993	46.936	45.950
Sim 8	11.826	17.531	16.122	11.826	17.460	16.122	41.070	47.274	46.327	41.070	47.274	46.327
Sim 9	9.024	12.292	11.516	9.024	12.292	11.516	39.512	46.095	44.944	39.512	46.095	44.944
Sim 10	10.569	15.283	14.163	10.569	15.283	14.163	40.409	46.612	45.611	40.409	46.612	45.611
Sim 11	9.991	11.327	11.010	10.569	13.889	13.101	40.101	44.775	44.110	40.346	46.221	45.208
Simulation	**Smallholders**			**Non Smallholders**			**Smallholders**			**Non Smallholders**		
	Urban	Rural	All	Urban	Rural	All	Urban	Rural	All	Urban	Rural	All
Base run	11.826	17.531	16.176	11.82	17.531	16.176	41.084	47.346	46.391	41.043	47.345	46.391
Sim 1	11.826	17.482	16.139	11.826	17.448	16.113	41.078	47.331	46.377	41.076	47.328	46.374
Sim 2	11.826	17.420	16.092	11.826	17.020	15.786	41.068	47.297	46.346	41.064	47.299	46.339
Sim 3	11.826	17.303	16.002	11.826	16.746	15.578	41.032	47.206	46.256	40.964	47.247	46.268
Sim 4	11.826	17.468	16.128	11.826	16.503	15.392	41.046	47.274	46.324	41.060	47.170	46.240
Sim 5	11.684	17.035	15.764	11.826	15.341	14.407	40.961	47.123	46.154	40.909	47.036	46.065
Sim 6	11.826	17.451	16.115	11.826	17.218	15.938	41.080	47.306	46.358	41.073	47.297	46.346
Sim 7	11.684	17.004	15.740	11.826	15.184	14.288	40.955	47.097	46.128	40.896	46.998	46.026
Sim 8	11.826	17.460	16.122	11.826	17.460	16.122	41.070	47.274	46.327	41.070	47.274	46.327
Sim 9	9.024	12.292	11.516	9.024	12.292	11.516	39.512	46.095	44.944	39.512	46.095	44.944
Sim 10	10.569	15.283	14.163	10.569	15.283	14.163	40.409	46.612	45.611	40.409	46.612	45.611
Sim 11	10.439	14.854	13.806	10.217	13.811	12.958	40.295	46.400	45.388	40.243	46.304	45.294

Source: Authors' calculations from TNPS-1

4. Conclusions

The seminal idea of this work stemmed out from evidence that a consistent growth in aggregate agricultural output between the end of '90s and 2007 has had negligible impact on poverty and nutrition of Tanzanian households. This is quite a counterintuitive result considering the growing literature on the ability of agricultural growth to be pro-poor. Therefore, a first research question is why did this happen. Indeed, a careful analysis of data shows that agricultural growth was driven by large-scale farmers and growth was geographically very unevenly distributed, affecting only a few regions of the country.

A second, more compelling, thrust to this study was the renewed interest towards agricultural development by the Tanzanian Government that has recently recognized the pivotal role of agriculture in reducing poverty and designed an Agricultural Sector Development Programme (ASDP). Therefore, a second research question is: what would be the impacts in terms of poverty and inequality reduction of most important agricultural development initiative by the Government of Tanzania, i.e. the ASDP?

In order to carry out this assessment a non-separable agricultural household model has been estimated. Such a model was required to analyze households' production and consumption decisions because of labour market failures, which implies that consumption decisions depend on production decisions. In order to capture this feature, a two-stage estimation strategy has been adopted: first the shadow prices of family labour has been estimated and then used to estimate the production and demand systems by means of a multi-input multi-output production system (*translog*) and a complete demand system (AIDS). The production and consumption decisions taken under labour market failures are thus interlinked through the family labour (which enters in the production system) and its counterpart in the consumption system, which is leisure; both prices are determined by the shadow wage as estimated in the first stage. The models above are able to capture adjustments in production (both in output and input) and consumption patterns resulting from specific policy interventions whose impacts are mimicked through simulations.

The results of the production system confirm the importance of land and household labour as productive factors, and the subsistence nature of farm production. Indeed, maize, which is largely the most important farm output, mainly grown as a subsistence self-consumed crop, has the lowest own-price elasticity, confirming to be weakly responsive to price changes. Since the own-price elasticities of other cereals and other crops categories are greater than one, the supply response is expected to be larger for other crops producers than for maize producers.

Moreover, all cross-supply elasticities are positive, revealing complementary relationships among the commodities. Own and cross-price input demand elasticities are generally higher than supply elasticities, revealing a significant price responsiveness by Tanzanian producers in using inputs. Moreover, output elasticities to wage rate shows that production is very responsive to household labour.

Finally, results show that maize and other cereals are product substitutes, while, as regard fixed inputs, irrigation and land are complements.

The estimation of the demand system reveals that the consumption of “richest” food items like meat, other cereals (sorghum, millet and wheat), eggs and diary, fish (and leisure) is very sensitive to own price changes. In addition, accordingly to theory, as income increases consumers tend to spend proportionately less on maize, pulses and fish, and more on meat, eggs, dairy products, beverages, as well as other foods.

After the estimation of the production-consumption model, the impact of a number of agricultural policies (namely those included in the ASDP) on poverty and distribution has been assessed. The change in the profit from the agricultural sector (as a result of these policies) is plugged into the demand model and eventually the new consumption vectors (in real terms) are generated.

Despite the simulation results are biased because they refers to a full implementation of ASDP policies, they are useful to give an idea of the direction of change should the ASDP be fully implemented.

These simulations show that, considering single agricultural policies within the ASDP package, mechanization (i.e. ox-plough adoption) is the most effective policy for increasing farm profits and, as a result, reducing poverty.

Overall, in the case of pro-poor targeting, the implementation of the whole ASDP package has a quite strong impact on poverty and inequality reduction (nearly 3.5 and 1.5 percentage points, respectively, in rural areas). In this case the results referring to poverty reduction are in line with expectations of the Tanzanian government about the impact of ASDP in reducing poverty. The results are even more impressive if the policies are implemented in a more realistic scenario that takes into account the actual change in food prices since the beginning of the food price crisis.

In case of absence of targeting, ASDP is far less effective in reducing poverty. This suggests that to achieve the poverty reduction objectives of ASDP, the interventions must be addressed to the poorest farm households. Of course, there is a trade-off: a more effective poverty reduction implies a higher implementation cost due to targeting.

Quite surprisingly, a targeting oriented to those who have relatively more land results in a more effective poverty reduction as well as inequality reduction. This is related to the crucial role played by land in farming: land is indeed the limiting factor for smallholders, whose very low land endowment prevents the possibility of increasing agricultural production and profit. This has two main policy implications: (i) there is a need, as recently recognized by the Tanzanian Government, for a new land reform facilitating the access to land for smallholders, and (ii) in absence of a land reform, if the policy objectives are the reduction in the overall inequality and poverty, it is better to target relatively larger farmer.

Finally, the increase in food prices has had a huge impact on households' welfare (*ceteris paribus*, food price crisis increased poverty by nearly 5 percentage points). This has an immediate policy implication: that is the government should intervene to reduce, although not to eliminate, price movements to prevent adverse effects in terms of poverty and income distribution.

Those results, though interesting, have the limitation of being obtained in a partial equilibrium analysis framework. But still, they can be seen as a first approximation to more sophisticated modeling approaches. This research is in fact part of a larger study where the micro-simulations of agricultural policies on households' welfare will be integrated into a dynamic computable general equilibrium model to predict the impacts of agricultural policies in Tanzania.

Anyway, we think that this thesis has managed, at lest partially, to answer to the research questions we have put at the beginning of this work. In particular we have constructed a model able to assess the current agricultural policies implemented by the Government of Tanzania, and, by simulating different targeting of these policies, able to answer to the following crucial question: are agricultural policies effectively pro-poor, and agriculture is still a key for increase households' welfare and escaping poverty and reducing inequality in Sub-Saharan Africa?

Although our study is modelled to the specific context of Tanzania, we firmly believe that agriculture can be very effective in reducing poverty and economic inequalities in Sub-Saharan Africa, and that Governments must be engaged in policies aiming to increase agricultural production. But, in order to agriculture an effective way to escape poverty and increase households' welfare, these policies must be highly pro-poor targeted, revealing the weak effectiveness of indiscriminate policies, even in a context such as Tanzania where there are no huge differences among farmers in terms of land and other inputs endowment.

Future efforts for an extension of this work will be addressed to a major geographical specification of the model and, as a consequence, of policy implications, in order to take into account in a more specific way the peculiarities of the Tanzanian agro-economic context. In addition, the land issue will be further considered in order to provide some policy implications for a possible land reform facilitating the access to land for smallholders, since we are absolutely convinced that a land reform in the context of Tanzanian agriculture is a win-win option, which improves equality as well as efficiency.

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Appendix

Annex 1 – Empirical Specification and Estimation Strategy

As noted in section 2.2, the econometric estimation of the model requires a two-stage estimation strategy, since shadow wage cannot be directly observed. Thus, at the first stage we have estimated the shadow prices of family labour for adult male, adult female and children, and in the second stage we have estimated the production system (profit and netput share functions) and the demand system.

a) Shadow Wage

The Cobb-Douglas production function is specified as follows

$$\ln Y_i = \sum_{j=1}^{n} \alpha_j \ln Z_{ij} + \sum_{k=1}^{m} \gamma_k d_{ik} + \varepsilon_i \qquad \text{(A.1)}$$

where Y_i represents the total value of agricultural output produced by farm household i, Z_{ij} is a vector representing the quantity of input j used by farmer i, d_k is a vector of location dummies. The inputs included in the vector Z_j are total land area, quantity of pesticides, quantity of inorganic fertilizers, quantity of organic fertilizers, hours of hired male labour, hours of hired female labour, hours of family adult male labour, hours of family adult female labour, hours of family child labour, the value of mechanization, an index about plots irrigation and an index of land quality. In addition, the age, sex and level of education of household head have been also included as proxies for management input. Finally, the distance of plots from principal roads and markets is included[39].

In order to take into account cluster effects, we estimated coefficients of equation (A.1) with fixed effects to obtain robust standard errors. Since input variables are expected to be endogenous regressors, instrumental variables (IV) have been used to estimate the Cobb-Douglas production function.

The shadow wage rate of family male, female and child labour hours have been calculated from the IV estimates of the Cobb-Douglas production function using the following formula:

$$\hat{w}_i = \frac{\hat{\alpha}_j \hat{Y}}{L_i}, \quad \text{i = 1, 2, 3} \qquad \text{(A.2)}$$

[39] In the regression all variable inputs are in logarithmic form. Given the presence of zero values in all inputs, except land, we added one to the logarithmic transformation of all input.

where $\hat{Y}$ is the predicted value of output derived from the estimated coefficient $\hat{\alpha}_j$. L_1, L_2 and L_3 are the total hours of labour by adult male, adult female and children, respectively.

Finally, a test of equality between marginal products of labour and the market wages has been carried out. Under the assumption that households maximize utility, the effective wage received by family members participating in the off-farm labour market should be equal to the marginal productivity of on-farm family labour (i.e. the shadow wage). Assuming there are no transaction costs in working off farm, the effective wage reported should be equal to the market wage. In order to test the equality of marginal productivity and wage rate we have followed Jacoby (1993), by estimating the following regression

$$\hat{W}_i = a + bW_i + u_i\,, \quad i = 1,2 \tag{A.3}$$

where $\hat{W}_i$ is the estimated shadow wage of adult male and female labour, W_i is the wage received by working in the market, and u_i is a random term probably including measurement error.

As shown above, utility maximization and efficiency of the labour market imply that $a = 0$ and $b = 1$. This means that the allocation of time between farm and market is made purely on efficiency grounds. The theory also implies that u_i is independent of the taste for work.

b) Farm Production System

A *translog* profit function has been estimated in order to obtain input and output elasticities. The profit function is written as

$$\ln \pi_{c,h} = a_0 + \sum_{i=1} a_i \ln p_{i,c} + \sum_{m=1} b_m \ln Z_{m,h} + \frac{1}{2}\sum_{i,j} b_{ij} \ln p_{i,c} \ln p_{j,c} \tag{A.4}$$

$$+ \frac{1}{2}\sum_{m,n} c_{mn} \ln Z_{m,h} \ln Z_{n,h} + \sum_{i,m} d_{im} \ln p_{i,c} \ln Z_{m,h} + \varepsilon_{i,h}$$

with the following restrictions:

$$b_{ij} = b_{ji} \qquad c_{mn} = c_{nm} \qquad \sum_i a_i = 1 \qquad \sum_m b_m = 1 \qquad \sum_i b_{ij} = \sum_m c_{mn} = \sum_i d_{im} = \sum_m d_{im} = 0$$

where $\pi_{c,h}$ is the profit of the household *h*, living in cluster[40] *c*, $p_{i,c}$ is the price of output or input *i* in cluster *j*, $Z_{m,h}$ is the fixed input *m* used by the household *h* and $\varepsilon_{i,h}$ is the residual term.

As regard the estimation procedure, the first step was to associate every crops cultivated in the 2008 long rainy[41] season[42] (*masika*) to a specific category of goods. All crops cultivated in the 2008 long rainy season have been grouped in three categories: maize, other cereals (including sorghum, millet and wheat), other crops (including tubers and roots, legumes, oil, fruits, vegetables and cash crops)[43].

Fertilizers (organic and inorganic) and pesticides, hired labour and family labour are considered as variable inputs. Thus, the expenditure in fertilizers and pesticides, household labour (calculated multiplying the days of labour times the daily shadow wage for adult male and female and children) and hired labour were computed and input shares calculated for the production system. Land, measured as hectares cultivated by farms, and irrigation, i.e. area-weighted average number of irrigations, have been considered as fixed inputs within the seasonal observation interval.

Since the relative shares on profit has to be taken into account for both input and output, the total value of output (real and imputed[44]) and the total value of input have to be estimated in order to obtain farm profits.

The second step was to obtain prices of crops and inputs. Unit values - production values divided by production quantities, as reported in the household survey – have been computed for each input and output category. Prices have been estimated as the median prices by cluster. For cluster without price information, median prices by larger geographic units were used.

At this stage, the *translog* profit function can be estimated. From equation (A.4), using the Hotelling's lemma, we obtain the share equations S_i.

$$S_i = \frac{\partial \ln \pi}{\partial \ln p_i} = \frac{p_i Y_i}{\pi} \qquad \text{(A.5)}$$

that are linear in normalized prices:

[40] In order to take into account regional differences in prices, we constructed clusters as a combination of regions, urban-rural location and districts, obtaining 173 clusters.

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

[42] The reference time for farm production is the 2008 long rainy season, both for crops cultivated and input used. Data regarding the short rainy season (*vuli*) have not been included in the empirical analysis since too few households cultivate during this season, implying the presence of too many missing values in the production system.

[43] This classification is determined by mapping the categories in the underlying micro data and then aggregating accordingly the commodities.

[44] For farms having not yet completed the harvest, the value of the output not yet harvested has been imputed and summed to the value of the harvested output.

$$S_i = a_i + \sum_{j=1} b_{ij} \ln p_j + c_i \ln Z \tag{A.6}$$

However, since the input and output shares sum to unity, one input or output equation is dropped from the system to avoid singularity problems. Thus, in the production system there are two output categories (maize and other cereals, S_1 and S_2, respectively) and three input categories (fertilizers and pesticides, household labour, hired labour, S_3, S_4 and S_5, respectively).

The share equation dropped is that of other crops, whose coefficients are obtained by using the adding-up property. Symmetry is imposed during the estimation of the system of equations. Profit, the price of inputs and the price of outputs are normalized by P_6, i.e. the price of the category excluded from the system.

Profit and shares functions are estimated simultaneously. Thus, the coefficients of the share equations in (A.6) must be the same of those in equation (A.4). This implies, among other things, that the sample farms, on average, maximize profits with respect to normalized prices of the variable inputs, thus empirically supporting the assumption of profit maximization[45].

There are four dummy variables in the profit function in order to capture the effect of other factors on production and to allow to carry out additional simulation[46], namely use of improved seeds, ownership of ox-plough, household head's education status (literate or not) and access to agricultural extension services.

Assuming farm price-taking behaviour the normalized input prices and quantities (levels) of fixed factors are considered to be the exogenous variables.

For statistical specification additive errors with zero expectations and finite variance are assumed for each of the equations of the model. The covariances of the errors of any two of the equations for the same farm may not be zero, but the covariances of the errors of any two equations corresponding to different farms are assumed to be identically zero. Thus, seemingly unrelated regression (SUR) was used. In addition, SUR allows to impose the symmetry and homogeneity constraints on the parameters.

Output supply and input demand elasticities to own price are expressed as

$$\eta_{ii} = \frac{\beta_{ii}}{s_i} + s_i - 1 \tag{A.7}$$

[45] Other empirical studies estimating simultaneously profit and shares functions are Sidhu and Baanante (1981); Gordon (1989); Chaudhary *et al*. (1998).

[46] Data allowed us to introduce these variables only as dummy: they are arguments of the profit function only, since they are not interrelated with prices (see, for example, Olson and Zoubi, 2001).

Price elasticities of other commodities or factor of production are:

$$\eta_{ij} = \frac{\beta_{ij}}{s_i} + s_j \tag{A.8}$$

c) Household Consumption Decisions

On the consumption side, an Almost Ideal Demand System (AIDS) proposed by Deaton and Muellbauer (1980) has been used to estimate the impact of changes in prices and income on households' consumption behaviour.

AIDS derives from a utility function specified as a second-order approximation to any utility function. The demand functions are derived as budget share as follows:

$$w_{j,c,h} = a_j + \sum_{k=1}^{K} b_{j,k} \ln p_{k,c} + c_j \ln \frac{x_{c,h}}{z(p_c)} + e_j D_{c,h} + \varepsilon_{j,h} \tag{A.9}$$

with the following restrictions:

$$\sum_{j=1}^{J} a_j = 1 \qquad \sum_{j=1}^{J} b_{jk} = 0 \qquad \sum_{j=1}^{J} c_j = 0 \qquad \sum_{j=1}^{J} e_j = 0 \qquad b_{jk} = b_{kj}$$

where $w_{j,c,h}$ is the budget share devoted by the household *h* living in cluster *c* to the commodity *j* and $p_{k,c}$ is a price index of that commodity in cluster *c*, $x_{c,h}$ is the per-adult equivalent household's total expenditure, z_c is the poverty line in cluster *c*, $D_{c,h}$ is a vector of socio-demographic characteristics of households, and $\varepsilon_{j,h}$ is the residual term.

The empirical procedure to estimate the demand system is quite similar to the one followed for the estimation of the production system. As the dependent variables are the expenditure shares on total expenditure, the first step was to associate every commodity in the household survey to a specific category of goods. We grouped households' expenditure in 12 categories of goods, i.e. 11 food categories[47] plus the value of leisure[48]. Food categories are: maize; rice; other cereals;

[47] It would be preferable to include a non-food expenditure (comprising expenditure in education, health related services, housing, other daily non-food or less frequent expenditure) category in the demand system. However, estimation results shows that only food-based poverty estimates were consistent with poverty estimates resulting from other sources in Tanzania (mainland headcount ratio was 16.6 percent in 2007, as reported by the Tanzanian National

starches; sugar and sweets; pulses, dry, nuts and seeds; vegetables and fruits; meat, eggs and dairy; fish; oil and fats; salt and spices; beverages.

Consumption values in the household survey must be converted to an annual basis when required. Total consumption is obtained by aggregating purchases, self-consumption and gift values over all household consumption categories to calculate total household consumption[49].

Individual consumptions per adult equivalent are calculated dividing total household consumption by the total number of adult equivalents[50] in the household (assuming a unitary model).

The next step was to obtain items categories' prices: the procedure mimics the one used for the production system estimation.

At this stage, the AIDS demand system can be estimated as specified by equation (A.9), in which budget shares are linear in b_{jk}, c_j and e_j. Equation (A.9) was estimated following Deaton (1997) and relying on the spatial variability of prices in Tanzania to estimate the parameters for price (b_{jk}), income (c_j) and of the socio-demographic characteristics (e_j). A three-stage least squares (3SLS) estimator was used to account for the endogeneity of $y_{c,h}$ and the generation of the shadow wage and to allow for contemporaneous correlation of the disturbance terms[51]. Indeed, household decisions regarding available food items are not completely independent; as a result, linear equations have correlated error terms. In this case, a 3SLS regression is preferred to ordinary least squares (OLS). In addition, 3SLS allows to impose the symmetry and homogeneity constraints on the parameters.

This approach allows to take into account substitution effects between consumer goods. It is also more flexible in taking account adjustments in household consumption patterns to variations in household income.

The adding-up property of the demand system requires that one of the expenditure share equations be dropped from the system to avoid singularity problems. The expenditure share

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Bureau of Statisics, and in our dataset it results equal to 16.1 percent). Thus, the demand system was estimated taking into account only food expenditure, i.e. to obtain "reliable" estimates of the real equivalent income.

[48] The amount of leisure was determined by calculating the yearly available time of households minus time spent in labour activities. It is assumed that each household member between 15 years and 60 years has 12 hours per day, each household member between 5 years and 14 years has 6 hours per day, and each household member older than 60 years has 6 hours per day available for work and/or leisure. The annual available time of the household is calculated by multiplying the total hours per day of all household members by 365. Time spent in labour activities comprises on-farm labour, other self-employment jobs, wage jobs and unpaid family activities. In order to estimate the value of leisure, the hourly shadow wage rate in agricultural activities has been multiplied by the hours of leisure per day.

[49] As food expenditure, the consumption of meals outside home was also included.

[50] For the calculation of adult equivalent, we use the "caloric requirements" approach to determine equivalence scales, with data from FAO/WHO. Detailed equivalence scales are reported in Annex 1.

[51] The three stage least squares model (3SLS) allows to estimate a system of structural equations where some equations contain endogenous variables among the explanatory variables. Typically, the endogenous explanatory variables are dependent variables from other equations in the system.

equation dropped is that of leisure, whose coefficients are obtained by using the adding-up property. Symmetry was imposed in the estimation of the system of equations.

After the estimation of the parameters in equation (A.9), which can be re-written as

$$w_{j,c,h} = a_j + \sum_{k=1}^{K} b_{j,k} \ln p_{k,c} + c_j \ln y_{c,h} + e_j D_{c,h} \tag{A.10}$$

where $y_{c,h} = \dfrac{x_{c,h}}{z_c}$ (A.11)

we calculated the consumption in real terms as

$$\ln e_{ch} = b(p_r)\left[\frac{\ln x_{ch} - \ln z(p_c)}{b(p_c)}\right] + \ln z(p_r) \tag{A.12}$$

where e_{ch} is what Kings (1983) defined the "equivalent consumption" and $z(p_c)$ and $b(p)$ are defined as

$$\ln z(p_c) = a_{0c} + \sum_{k=1}^{K} a_k \ln p_{ck} + \frac{1}{2}\sum_{j=1}^{J}\sum_{k=1}^{K} b_{jk} \ln p_{cj} \ln p_{ck} \tag{A.13}$$

which can be approximated by the poverty line[52] in strata c, and $b(p)$ is a price index

$$b(p) = c_0 \prod_j p_j^{\,c_j} \,. \tag{A.14}$$

The own price elasticity (ε_{jj}) for j-th good is

$$\varepsilon_{jj} = \left(\frac{b_{jj}}{\bar{w}_j}\right) - 1 \,. \tag{A.15}$$

[52] Since there is not an official poverty line for 2008/2009, we used the official food poverty line reported for 2007 (reported in GoT, 2009) deflated by the food inflation rate for 2008 and 2009 reported in Tanzania National Panel Survey Report, Round 1.

The cross price elasticity ε_{jk} between good *j* and good *k*'s price is

$$\varepsilon_{jk} = \frac{b_{jk}}{\bar{w}_j}. \tag{A.16}$$

The income elasticity (ηj) is

$$\eta_j = \frac{\mu_j}{\bar{w}_j} + 1 \tag{A.17}$$

where $\mu_j = c_j$.

Annex 2 – Estimation of policy impacts on poverty and inequality

In order to capture the impact on households' welfare determined by changes in production behaviour due to agricultural policies and prices changes, poverty and inequality estimates have been carried out.

a) Monetary poverty

The standard Foster-Greer-Thorbecke (1984) (FGT) measures of monetary poverty (headcount ratio and poverty gap) have been calculated for the base scenario (i.e. the scenario without simulations) and for each simulation scenario. Absolute changes in household income are fully transmitted to household consumption with the hypothesis that there is no change in savings.

The FGT indices are averages of powers α of normalized poverty gaps, $\frac{z - e_h}{z}$, where *z* is the real poverty line estimated in terms of reference prices and e_h is the equivalent consumption as in equation (A.12).

The FGT indices can be formalized as

$$P_\alpha(z) = \frac{1}{N}\sum_{h=1}^{H} \rho_{c,h} n_{c,h} \left(\frac{z - e_h}{z}\right)^{\alpha} \tag{A.18}$$

where N is the number of the households in the survey, n_h is the size of the household h in cluster c, ρ_h is the sampling weight of h in cluster c, and α is a parameter that measures the distribution sensitivity of the poverty index. A larger α gives a greater weight to a loss of income to the poorest than to the richest. Thus, according to different values of α, $P_\alpha(z)$ gives different measures of poverty: $P_0(z)$ measures the incidence of poverty (headcount ratio (HCR)), $P_1(z)$ measures the depth of poverty (poverty gap), and $P_2(z)$ measures the squared poverty gap[53].

The empirical procedure requires that total real consumption per adult equivalent, as calculated in equation (A.12), be normalized by dividing it by the relevant cluster poverty line, as calculated in equation (A.13), and then multiplying it by 100. Thus, the new poverty line is 100 for all individuals in all clusters. In order to calculate the poverty rates for each simulation scenario, we need to re-estimate total real consumption using the new vector of prices and the change in total household income, as obtained from equation (A.12). In addition, the variation of profit of farm households after simulations has to be included in the total real consumption per adult equivalent, expressed as

$$\ln e_{ch} = b(p_r)\left[\frac{\ln(x_{ch} + \Delta\pi(ae)) - \ln z(p_c)}{b(p_c)}\right] + \ln z(p_r) \qquad \text{(A.19)}$$

where $\Delta\pi(ae)$ is the profit variation per adult equivalent.

Finally, it is necessary to recalculate the poverty line for each simulation scenario and each year according to the new price vectors, calculated from equation (A.13).

Therefore, the potential impact on poverty of a policy change can be measures as

$$\Delta P_\alpha(z) = \frac{1}{N}\left(\sum_{h=1}^{H}\rho_{c,h}n_{c,h}\left(\frac{z-e_{s,h}}{z}\right)^{\alpha} - \sum_{h=1}^{H}\rho_{c,h}n_{c,h}\left(\frac{z-e_{0,h}}{z}\right)^{\alpha}\right) \qquad \text{(4.20)}$$

where $e_{0,h}$ and $e_{s,h}$ are the equivalent consumption pre and post policy change, respectively.

b) Income inequality

In order to assess the distributional impact of agricultural policies and prices changes, the Gini index has been calculated.

[53] In this analysis only the headcount ratio ($P_0(z)$) has been calculated.

We used the total real consumption per adult equivalent (including the variation of profit after simulations), as expressed in equation (A.19).

The Gini index for simulation *s* can be formalized as

$$G_s = \frac{1}{N}\left(N + 1 - 2\frac{\sum_{i=1}^{N}(N+1-i)e_{s,h}}{\sum_{i=1}^{n} e_{s,h}} \right) \tag{A.21}$$

where $e_{s,h}$ is the equivalent consumption for simulation *s*.

As in the case of poverty estimates, the potential impact on inequality of a policy or price change can be measures as G_s - G_0, where G_0 is the level of Gini index pre-simulation.

Annex 3 – List of Variables

Table A1

Definitions, means and standard deviations of variables used in main empirical specifications

Variable Name	Definition	Mean	Std. Dev.
loutput_value(*)	log of output value	11.71	1.37
lhh_land(*)	log of land area (acres)	1.51	0.74
lhh_pesticides(*)(!)	log of quantity of pesticides used	0.21	0.73
lhh_inorganic_fert(*)(!)	log of quantity of inorganic fertilizers used	0.57	1.50
lhh_organic_fert(*)(!)	log of quantity of organic fertilizers used	1.04	2.35
lhh_tot_lab_f(*)(!)	log of quantity of female family labour (days)	3.82	1.50
lhh_tot_lab_m(*)(!)	log of quantity of male family labour (days)	3.45	1.86
lhh_tot_lab_child(*)(!)	log of quantity of child family labour (days)	0.73	1.50
lhired_female(*)(!)	log of quantity of female hired labour (days)	0.96	1.40
lhired_male(*)(!)	log of quantity of male hired labour (days)	0.65	1.20
hhhead_age(*)	hh head age (years)	47.50	15.52
hhhead_age^2(*)	hh head age squared (years)	2524.59	1622.61
hhhead_sex(*)	dummy: 1 if hh head is male	0.75	0.43
primary	dummy: 1 if hh head has primary education as highest grade completed	0.64	0.48
secondary_plus	dummy: 1 if hh head has secondary education or more as highest grade completed	0.07	0.26
land_quality(*)	average of quality index of total household's plots (1=bad; 2=average; 3=good)	2.46	0.53
irrigation(*)	average of dummy irrigation of total household's plots (1=irrigated)	0.03	0.16
lroad(*)(!)	distance to road (km)	0.84	0.66
lmarket(*)(!)	distance to market (km)	1.75	0.87
agr_zone1(*)	agro-region dummy variable (1 if agro-region1(i); 0 otherwise)	0.28	0.45
agr_zone2(*)	agro-region dummy variable (1 if agro-region 2; 0 otherwise)	0.32	0.47
agr_zone3(*)	agro-region dummy variable (1 if agro-region 3; 0 otherwise)	0.20	0.40

agr_zone4(*)	agro-region dummy variable (1 if agro-region 4; 0 otherwise)	0.15	0.35
urban	Dummy variable (1 if household lives in urban areas; 0 otherwise)	0.37	0.48
hhhead_age_class1	dummy variable (1 if household head< 36; 0 otherwise)	0.22	0.42
hhhead_age_class2	dummy variable (1 if household head>35 and <46; 0 otherwise)	0.27	0.44
hhhead_age_class3	dummy variable (1 if household head>45 and <61; 0 otherwise)	0.32	0.47
hhhead_age_class4	dummy variable (1 if household head>60; 0 otherwise)	0.19	0.39
lmechanization(*)(!)	log of value of agricultural mechanization	9.07	2.28
S_1 - production(*)	Share of the value of maize produced on profit	1.34	5.21
S_2 - production(*)	Share of the value of other cereals produced on profit	0.71	6.63
S_3 - production(*)	Share of the value of fertilizers and pesticides used on profit	-0.64	5.90
S_4 - production(*)	Share of the value of household labour used on profit	-1.81	7.31
S_5 - production(*)	Share of the value of hired labour used on profit	-0.54	3.90
S_6 – production(*)	Share of the value of other crops produced on profit	1.40	6.10
S_1 - consumption	Share of the value of maize consumed on total expenditure	0.13	0.14
S_2 – consumption	Share of the value of other cereals consumed on total expenditure	0.12	0.13
S_3 – consumption	Share of the value of starches consumed on total expenditure	0.09	0.13
S_4 – consumption	Share of the value of sugar and sweets consumed on total expenditure	0.04	0.04
S_5 – consumption	Share of the value of pulses, dry, nuts and seeds consumed on total expenditure	0.08	0.09
S_6 – consumption	Share of the value of vegetables and fruits consumed on total expenditure	0.10	0.10
S_7 - consumption	Share of the value of meat, eggs and dairy consumed on total expenditure	0.10	0.12
S_8 – consumption	Share of the value of fish consumed on total expenditure	0.05	0.07
S_9 – consumption	Share of the value of oil and fats consumed on total expenditure	0.03	0.04
S_{10} – consumption	Share of the value of salt and spices consumed on total expenditure	0.01	0.01
S_{11} – consumption	Share of the value of beverages consumed on total expenditure	0.06	0.09
S_{12} – consumption	Share of the value of leisure on total expenditure	0.22	0.27
lnP_1 - production(*)(!)	Price of maize normalized by other crops' price (P_6)	0.28	0.36
lnP_2 - production(*)(!)	Price of other cereals normalized by other crops' price (P_6)	0.35	0.37

lnP_3 - production(*)(!)	Price of fertilizers and pesticides normalized by other crops' price (P_6)	2.02	1.56
lnP_4 - production(*)(!)	Price of household labour normalized by other crops' price (P_6)	0.27	0.34
lnP_5 - production(*)(!)	Price of hired labour normalized by other crops' price (P_6)	1.17	0.72
lnP_1 - consumption	Price of maize consumed on total expenditure	6.18	0.61
lnP_2 – consumption	Price of other cereals consumed on total expenditure	7.12	0.12
lnP_3 – consumption	Price of starches consumed	6.12	0.30
lnP_4 – consumption	Price of sugar and sweets consumed	7.31	0.19
lnP_5 – consumption	Price of pulses, dry, nuts and seeds consumed	7.25	0.19
lnP_6 – consumption	Price of vegetables and fruits consumed	6.65	0.29
lnP_7 - consumption	Price of meat, eggs and dairy consumed	7.90	0.24
lnP_8 – consumption	Price of fish consumed	7.76	0.27
lnP_9 – consumption	Price of oil and fats consumed	7.73	0.18
lnP_{10} – consumption	Price of salt and spices consumed	6.67	0.31
lnP_{11} – consumption	Price of beverages consumed on total expenditure	8.50	0.46
ox(*)	dummy variable (1 if household owns at least ox-plough; 0 otherwise)	0.08	0.26
extension(*)	dummy variable (1 if household receives extension services; 0 otherwise)	0.23	0.42
improved(*)	dummy variable (1 if household uses improved seeds; 0 otherwise)	0.18	0.38
literate(*)	dummy variable (1 if household head is literate; 0 otherwise)	0.72	0.45
irrigation(*)(!)	average of dummy irrigation of total household's plots (1=irrigated) weighted by land acres	1.02	0.13
children(*)	number of children per household	2.20	1.91
lnhhsize(*)	log of household size	1.46	0.62
ln_profit	log of absolute value of household profit normalized by other crops' price (P_6)	4.32	1.68
ln_y_equiv	log of per adult expenditure deflated by poverty line	0.83	0.74

(*) refers to farm households only

(!) Given the presence of zero values we added one to the logarithmic transformation

(i) *agro-region1*: Dodoma, Tanga, Morogoro, Dar es Salaam, Zanzibar, Pemba; *agro-region2*: Arusha, Kilimanjaro, Kigoma, Shinyanga, Kagera, Mwanza, Mara; *agro-region3*: Mbeya, Singida, Tabora, Rukwa; *agro-region4*: Lindi, Mtwara, Ruvuma, Iringa

Source: Authors' calculations from TNPS-1