Modelling farm-household level impacts of fertilizer subsidy programs on food security: The case of Ethiopia

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Abstract

Fertilizer subsidy program is one of the most well-known and politically sensitive policies in Sub-Saharan countries. It started up in the 1980s, declined in the 1990s, and recently reintroduced for food price purpose. Two categories of fertilizer subsidy programs are often used at large-scale to improve smallholder farmers' production and boost their incomes: universal and targeted programs. This paper aims to assess the potential impacts of these two programs on the viability of a nationally representative sample of farm households in Ethiopia. A farm-household model, called FSSIM-Dev (Farm System Simulator for Developing Countries), is used for this purpose. Based on Positive Mathematical Programming, FSSIM-Dev seeks to improve the quality of policy assessment upon existing aggregate models and to provide assessment of distributional effects over the farm sample. Results show that the impacts of 50% fertilizer subsidies, given under both targeted and universal programs, on production and farm income is rather limited: farm income raise by less than 1% in most cases and only 15% of the farm households will be positively affected. Nevertheless, for a small number of smallholder farmers the income effect could be more substantial (more than +50%) which may improve their access to food and, thus, food security.

Keywords: Food security, Fertilizer subsidy programs, Farm household model, Ethiopia

[1] The authors are solely responsible for the content of the paper. The views expressed are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission.

1. Introduction

According to the World Bank's estimates (2015), 78% of the world's extreme poor (i.e. with less than 1.25 USD-equivalent per person and day) were concentrated in rural areas, and most of them were involved in farming. Although poverty continues to decline in many countries, major progress is yet to be made in Sub-Saharan Africa (SSA) and South Asia's rural areas where most of the population is extremely poor (i.e. 52% of rural population in SSA and 27% of rural population in South Asia) and dependent on small holdings (FAO, 2015). In Sub-Saharan Africa, farm households are confronting persistent low levels of agricultural productivity and food insecurity and more than one policy intervention is needed to meet their needs.

Many programs have been initiated by governments and donors in the region to improve agricultural productivity and food security, however with mixed performance to date. Among such efforts, we may mention input subsidy programs, including access to irrigation, improved seed varieties and inorganic fertilizers, output price support programs and long run investment programs such as investments in roads, education and agricultural R&D (WB, 2008; Sanchez et al., 2007; Barrett and Carter, 2013).

Fertilizer subsidy program is one of the most well-known and politically sensitive policies. It started up in the 1980s, declined in the 1990s during the structural adjustment period, and recently reintroduced, triggered by concerns on food price crises and growing food insecurity in SSA. Countries such as Malawi, Nigeria, Ghana and Ethiopia are characterized by large funded fertilizer subsidy programs in recent years. Malawi, Ghana and Nigeria administer a targeted input subsidy program (e.g. fertilizer voucher program), while Ethiopia uses a universal subsidy program where the government imports fertilizer and distributes it among farmers at below-market price through the network of cooperative unions. These two programs, highly discussed in the literature, often rise a debate between those who sustain their effectiveness in bringing about an African green revolution (Denning et al., 2009; Javdani, 2012; Sachs, 2012) and those who considers them inefficient given their high, possibly unsustainable costs and inconsistent farm-level impact and development outcomes (Chibwana et al., 2014; Holden and Lunduka, 2010; Ricker-Gilbert et al., 2011).

This paper aims at contributing to this debate by assessing the likely impacts of these two fertilizer subsidy programs (universal and targeted programs) on the livelihoods of farm households in Ethiopia, taken as a case study. A novel farm-household model, FSSIM-Dev (Farm System Simulator for Developing Countries), is used to model both programs and to assess their potential effects on land allocation, production and income on a representative sample of farm households in Ethiopia.

The paper is structured as follows: in section 2, a short review of the implemented large-scale fertilizer subsidy programs in Sub Saharan Africa is provided, followed by a brief description of the Ethiopian experience in such programs. In section 3, the modelling framework is exposed. In section 4, the data used and the simulated scenarios are described and their results are presented and discussed in section 5. In section 6, we conclude on the relevance of

this type of modelling framework and stress the value added of our results in comparison with other studies.

1.1. African experiences with fertilizer subsidy programs

As pointed out by several authors there is a lack of systematic and good quality information on subsidy programs in Sub-Saharan Africa, despite the substantial number of programs that have been or are being implemented across SS Africa (Dorward, 2009b; Morris et al., 2009; Kelly et al., 2011, Druilhe and Barreiro-Hurlé, 2012). We summarise here only the very common ones selected on the basis of (a) availability of information and (b) their large-scale implementation. Most of these programmes aimed to boost food production and to raise household food security and income. They have also been associated at times with other policy objectives, such as reducing poverty of smallholder households and/or supporting the development of dynamic input supply markets (Druilhe Z., Barreiro-Hurlé J., 2012).

The first category of fertilizer program is the targeted program to certain categories of farmers and sectors. It is implemented in some East Africa such as Kenya, Malawi, Rwanda, United Republic of Tanzania, Zambia and recently Nigeria and Ghana (not for cotton producers). Under this program smallholder farmers growing targeted crops (usually maize, legumes or rice) and fulfilling certain allocation criteria (e.g. farm size, female-headed households) are eligible and receive a certain volume of subsidised fertilizer (and sometimes a package with seeds). In most of the countries, targeted fertilizer subsidies are implemented through vouchers such as in Malawi, Kenya, the United Republic of Tanzania or Ghana (Druilhe and Barreiro-Hurlé, 2012, Brooks et al., 2010). These vouchers allow transferring purchasing power to smallholder farmers by reducing the costs of purchased fertilizer (i.e. purchasing price is below the market price). This fertilizer price/cost reduction (FH) differs per country and is limited to a certain volume of fertilizer, as it is showed in Table 1.

Table 1: Targeted fertilizer policies

Country	Volume of fertilizer under subsidy per farm household (FH)	Price reduction (%)
Malawi	50 kg/FH (Urea) +50 kg/FH (basal fertilizer)	64 – 93
Kenya	50 kg/FH (DAP)	100
Tanzania	50 kg/FH (Urea) +50 kg/FH (DAP)	50
Ghana	No limit	26 (compound) - 20% (urea)
Nigeria	100/FH (Urea and NPK)	40
Zambia	200/FH (D-compound and Urea)	50 – 75

Source: Dorward and Chirwa (2011), Kato and Greeley (2016), Druilhe and Barreiro-Hurlé (2012)

The success of input voucher schemes in East Africa as an entitlement system is, however, largely contingent on implementation (fraud and leakage resulting from reselling of vouchers). They can also be quite costly to implement due to administration and monitoring costs (Druilhe and Barreiro-Hurlé, 2012).

By contrast, other SSA countries as it is the case of Burkina Faso, Mali, Senegal and partially Ghana, administer a fertilizer program that seems to revert to universal price subsidies but targeted specific crops. For example, in Burkina Faso, government's intervention is universal

but targeted to maize and rice. This subsidy decreases the market price of fertilizers by 20-40% for farmers growing maize and rice (Wanzala-Mlobela et al., 2013; Siri, 2013). In the case of Mali, the Rice Initiative (Initiative Riz) aims at increasing rice production by subsidizing chemical fertilizers and investing in the expansion of irrigated land for rice. The new subsidy allows rice farmers to buy fertilizer at around 50% of its purchase price. In Senegal, the government determines the price at which it purchases fertilizers from private suppliers and a price to be paid by farmers, after the 50% subsidy. Quota systems are used among suppliers, who first sell fertilizers to farmers at the government's set price and then collect the subsidies from the government. In Ghana, for cotton producers under recognised nucleus farmers and companies there is not a prerequisite of being small, implying the subsidy a price reduction of 26% for compound fertilizer and 20% for urea.

1.2. The case of Ethiopia

Agriculture is still of major importance in Ethiopia accounting for 42.3% of total GDP in 2014 and 80% of employment (African Development Bank Group, 2015). Smallholder households are prevalent in agriculture and nearly 55% of smallholders operate on one hectare or less. Cereals are the main crop within smallholders, occupying 80.3% of the grain crops area and 87% of the production, followed by pulses with 13.3% of the grain crops area and 10% of production in 2014-15 (African Development Bank Group, 2015). Small size of farms, jointly with low input-low output and rainfed farming systems make households very vulnerable to any market or environmental shock (Headey et al., 2013). Thus, rising prices of agricultural inputs cause difficulties for smallholder farmers to adopt technologies. Moreover, soil erosion due to over-cultivation or cultivation of marginal lands cause real constraints for improving agricultural productivity.

Ethiopia reformed its fertilizer policy in 1992 towards a free market. At that date, the Ethiopian government liberalized the existing monopoly on fertilizer importation and distribution (Spielman et al., 2010). Despite the liberalization, the entry of holding companies strongly related with the government limited the competition between the government, private and holding companies. As a result, in 2002, only the governmental Agricultural Input Supplies Enterprise (AISE) and the holding companies were responsible for all fertilizer imports and distribution (Jayne et al., 2003). In 2007, the cooperatives were also involved in fertilizer imports, in order to encourage the participation of farmers' organizations. However, some problems derived from the high fertilizer costs made that only the Government intervenes in fertilizers imports since 2009.

Imports are executed through the AISE, and the Commercial Bank of Ethiopia (CBE) is the responsible of making payments to the international supplier(s) of fertilizers and to provide credit to the cooperative unions. From the port, fertilizers are distributed to the cooperative unions' warehouses or primary cooperatives in case unions do not exist (International Fertilizer Development Centre, 2012). The regional Bureaus of Agriculture and Rural Development (BOARDs) play an important role at this step, since they provide credit guarantees to the CBE for the cooperative unions and primary cooperatives to buy and transport fertilizers. So, at a first step, AISE delivers fertilizers at a fixed price, and

afterwards, this price is increased by the BOARD in order to include transport costs, warehouse costs, bank interest rates and other administrative costs (Rashid et al., 2013). Finally, primary cooperatives sell fertilizers to farmers mainly in cash, or as a combination of cash and credit (50/50) in remote areas. As a result of this policy based on a centralized fertilizer acquisition system, fertilizers retail prices are 10-30% lower in Ethiopia than in other neighbouring countries. On average, retail prices for Urea and DAP are 15% lower than in Kenya, 30% lower than in Malawi, 12% than in Rwanda and 23-29% lower than in the United Republic of Tanzania (Rashid et al., 2013). This difference is partly explained by existing below-market interest rate for fertilizers in Ethiopia, the lack of spoilage and storage costs and below-market cooperative margin rates. Since no cooperative margins are allowed, fertilizer trade is unprofitable for primary cooperatives, and seems to be unsustainable at long run.

Given the multiplication of the input subsidy programs in different African countries and the absence of consensus on their effectiveness, the main aim of this study is to contribute on this debate by simulating the farm-household level impacts of selected fertilizer subsidy programs on beneficiary farmers' production, income and food security. Particular attention will be given to the programs targeting vulnerable farmers and staple crops.

2. Materials and methods

2.1. Overview on the farm household model - FSSIM-Dev

FSSIM-Dev (Farming System Simulator for Developing Countries) is a micro-simulation tool conceived to be used in the specific context of low income developing countries to gain knowledge on food security and rural poverty alleviation (Louhichi and Gomez y Paloma, 2014). It is a non-linear optimization model which relies on both the general household's utility framework and the farm's production technical constraints, in a non-separable regime. Such framework is suitable for analysing the decisions of farmers who are not fully commercialized or who operate with missing or imperfect markets.

FSSIM-Dev takes into consideration five key features of developing countries' agriculture, such as non-separability of production and consumption decisions, interaction among farm households for market factors, heterogeneity of farm households with respect to consumption baskets and resource endowments, inter-linkage between transaction costs and market participation decisions, and the seasonality of farming activities and resource use.

FSSIM-Dev maximises farm household income subject to resource constraints (includes land and labour), cash, market clearing conditions, linear expenditure system (LES), price bands and complementary slackness conditions.

$$\text{Max } U = \sum_h w_h R_h$$

s.t.:

Resource constraints (land and labour)

Linear expenditure system (LES)
Price bands & complementary slackness conditions
Market clearing conditions
Cash constraint

where **U** is the value of the objective function, **h** denotes a farm household and **w** its weight within the village, region or country and **R** is the farm household expected full income. For more details on the mathematical structure of the model and its functioning, see Louhichi and Gomez y Paloma (2013).

Farm household income (**R**) is defined as the income earned from all economic activities of a family living in the same household and is composed of three components: agricultural income, income from marketed factors of production (non-farm wages, rent of land and equipment) and off-agricultural/farm incomes. Agricultural (farm) income is defined as the value that farm-households have earned by selling or consuming their own agricultural products (i.e. self-consumption).The off-farm incomes are exogenously defined and can originate from different sources such as non-farm salaries, petty trading, self-employed craftsmanship, pensions, transfer, donations, etc.

Agricultural (farm) income is computed as the sum of agricultural gross margin minus a non-linear (quadratic) activity-specific function. Gross margin is the total revenue from agricultural activities, including sales and self-consumption, minus the accounting variable costs of production activities. The accounting costs include costs of seeds, fertilizers and crop protection costs. The quadratic activity-specific function is a behavioural function introduced to calibrate the farm model to an observed base year situation, as is usually done in Positive Mathematical Programming (PMP) models. The PMP methodology (Howitt, 1995), recently refined by Mérel and Bucaram (2010), intends to replicate households' production and consumption decisions in a precise way, allowing to capture the effects of factors that are not explicitly included in the model such as price expectation, risk-adverse behaviour, labour requirement, capital constraints and other unobserved costs (Heckelei, 2002).

The mathematical formulation of the agricultural (farm) income is the following[2]:

$$\mathbf{Z = (p \circ y)'x - C'x - d'x - 0.5x'Qx}$$

where **Z** is the Agricultural (farm) income, **x** is the (N×1) vector of non-negative activity levels (i.e. acreages) for each agricultural activity *i*, **p** is the (N×1) vector of producer prices, **y** is the (N×1) vector of crop yields, **C** is the (K×N) matrix of accounting unit cost for K input categories (seed, fertilizer and plant protection), **d** is the (N×1) vector of the linear part of the behavioural activity function and **Q** is the (N x N) symmetric, positive (semi-) definite matrix of the quadratic part of the behavioural activity function.

Figure 1 summarises the data needs for running FSSIM-Dev and the main outputs that can generated by the model for a specific policy scenario.

(2) The symbol ∘ indicates the Hadamard product.

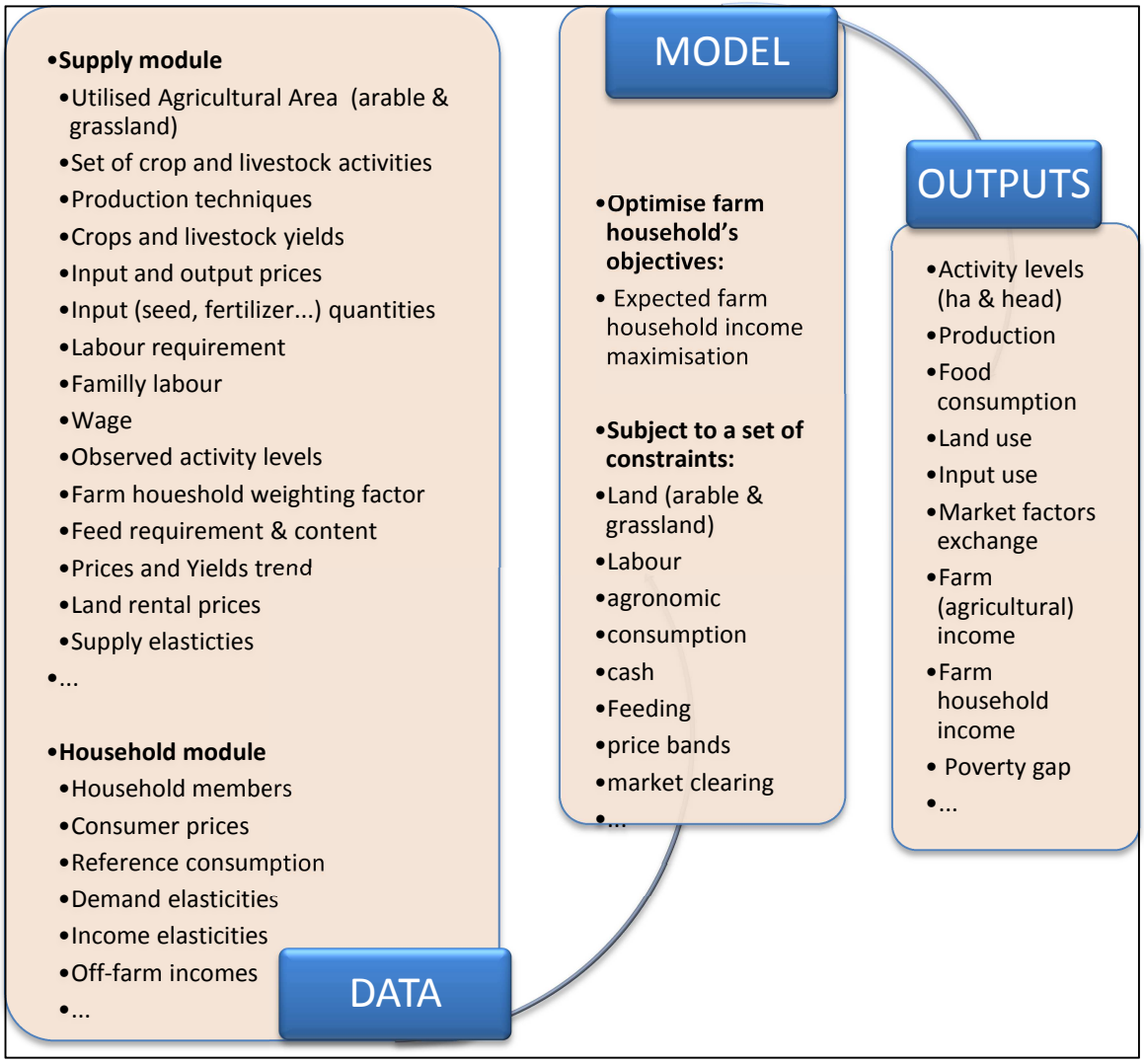


Figure 1. An overview of FSSIM-Dev - inputs & outputs -

For the present study, the consumption module of FSSIM-Dev was switched-off due to missing data on income elasticities and reference consumption. The calibration of the supply module was performed at the individual farm household level using the Highest Posterior Density (HPD) estimator with prior information on supply elasticities (Louhichi et al., 2015). Model parameters were calibrated so that the model exactly replicates an observed land allocation as well as an exogenous set of supply elasticities. The calibration to the exogenous supply elasticities is performed in a non-myopic way, i.e. we take into account the effects of changing dual values on the simulation response (Heckelei, 2002, Mérel and Bucaram, 2010). The parameters of the behavioural function are estimated only for observed activities in each farm household, meaning that the well-known self-selection problem is not explicitly handled in this estimation. To cope with this problem, we adopted the following ad-hoc modelling decisions in the simulation phase: the gross margin of the non-observed activities is equal to the region average gross margin, the activity's quadratic function parameter is equal to the activity's average quadratic function parameter within the region, and the linear term's quadratic function is derived from the difference between the gross margin and the dual values of constraints.

2.2. Description of the Sample

FSSIM-Dev is implemented in this study in a sample of smallholder farmers in Ethiopia using the Agricultural Sample Survey (AgSS) data for the cropping season 2014/2015. AgSS is an extensive survey that collects data on area and production, yields and inputs use from smallholder and commercial farms, considering that approximately 95% of the annual production in Ethiopia. We count with information for more than 2,100 enumeration areas, in which around 40,000 agricultural households were interviewed each year. Enumeration areas were selected on the basis of the 2001 cartographic census framework.

AgSS survey provides data on crop production and inputs use in each plot and farm, however information on input (i.e., DAP, urea and seed) and output prices are not collected. In order to overcome this limitation we have used information from the 2013-14 Living Standard Measurement Survey – Integrated Survey of Agriculture (LSMS-ISA), developed by the World Bank. The LSMS-ISA sample includes 5,262 households involved in agriculture and living in rural areas and small town across Ethiopia, being representative at the national level.

For this research, we focused on the regions with dominance of smallholder farming (i.e. average farm size less than 1 ha) and where the average fertilizer application rates are relatively low. This results in the selection of the following five regions: Afar, Somali, Benishangul-Gumuz, Harar and Dire Dawa.

The final size of our sample is 3797 farm households, which represents around 350.000 farm households in the selected regions. The key features of the sample are presented in Table 2. In order to guarantee the highest representativeness of the farming systems and to capture the full heterogeneity across smallholder farms, FSSIM-Dev was applied to every individual farm household in the sample.

Table 2: Sample characteristics

Regions	Afar	Somali	Benishangul-Gumuz	Harar	Dire Dawa
Number of surveyed farm households	505	864	1 673	403	352
Total surveyed area (ha)	223	929	2 097	231	190
Average farm size (ha)	0.44	1.07	1.25	0.57	0.54
St. Dev. farm size (ha)	0.71	1.78	1.52	0.52	0.56
Number of farms using urea	8	15	300	181	37
Average urea used (kg/ha)*	47.51 (81.03)	46.80 (60.94)	40.41 (41.51)	145.12 (102.86)	36.87 (47.93)
Number of farms using DAP	4	15	452	145	18
Average DAP used (kg/ha)*	48.13 (38.01)	34.19 (26.82)	49.36 (54.31)	86.25 (87.18)	29.07 (26.87)
Number of farms using improved seeds	59	16	311	72	182
Land use (% by region)					
Maize	18.91	16.19	16.09	7.69	
Millet			8.96		
Sorghum	9.30	16.23	20.93	33.40	46.06
Teff			7.77		
Wheat		4.58			
Sesame			16.80		
Groundnuts			4.16	14.25	
Chat				23.53	9.34
Masho	7.06				
Grazing land	37.00	43.82			6.53
Others crops	27.73	19.18	25.29	21.13	38.07

* Standard deviation in parenthesis

FSSIM-Dev is used in this study to explore the potential effects of various agricultural input policies in the five selected regions. Specifically, we simulate the impacts of four policy scenarios, including:

- **Univ-S1:** fertilizer subsidy equal to 50% of the current fertilizer price (i.e. 50% DAP and/or UREA prices) without limitation of the subsidised quantities (universal programs).
- **Univ-S2:** fertilizer subsidy equal to 50% of the current fertilizer price with a limitation of the subsidised quantities to 50Kg per farm (universal programs).
- **Targ-S1:** fertilizer subsidy equal to 50% of the current fertilizer price without any limitation on the subsidized quantity, targeting only smallholder farmers having between 0.5 and 1 ha (targeted programs).
- **Targ-S2:** fertilizer subsidy equal to 50% of the current fertilizer price with a limitation of 50Kg/farm on the subsidized quantity, targeting only smallholder farmers having between 0.25 and 1 ha (targeted programs).

The exclusion of very small farms (less than 0.25 ha) in the targeted subsidy program is driven by the fact that these farmers may not be in a position to use fertilizer, or to use it optimally, because they are not familiar (do not perceive the benefits), and/or cannot afford to pay the 50% remaining fertilizer costs. For very smallholder farmers, a direct cash transfer to boost their income and improve their food security seems to be more relevant. However, we

cannot assess the effectiveness of such transfer policy with this model since the data on household consumption are missing.

The effects of the simulation scenarios are compared to a baseline (reference) scenario interpreted as a projection in time including the most probable future development in terms of technological, structural and market changes. In our case study, the baseline scenario is assumed to be similar to the baseyear which means that all model parameters are assumed to remain unchanged including output prices, yields, variables costs, implicit costs (i.e. PMP terms), farm resource endowments and farm weighting factors (no structural change). As in the baseyear, the exchange of production factors between farms is not allowed (i.e. there are no land or labour markets).

3. Results and discussions

The impacts of the simulation scenarios are shown using a set of economic indicators generated from FSSIM-Dev at farm household level, subsequently aggregated at region or country level. These indicators are: land allocation among different crops (i.e. activity level), crop production and agricultural income. All the results are expressed in relative change to the baseline.

In the baseline, out of the 350.000 smallholder farmers represented in this study, only 15 % are applying fertiliser (either DAP or Urea or both); the remainders (85 %) are producing without fertilisers. The regions with the largest number of fertiliser users are Harari and Dire Dawa. They are also the ones with largest number of improved seeds users. In the contrary, the Afar and Somali regions have the lowest number of users of fertiliser and improved seeds. The latter regions have the high proportion of very smallholder farms in the total sampled farms. The average application rate of fertiliser is, as expected, low in the majority of the selected regions (Table 2).

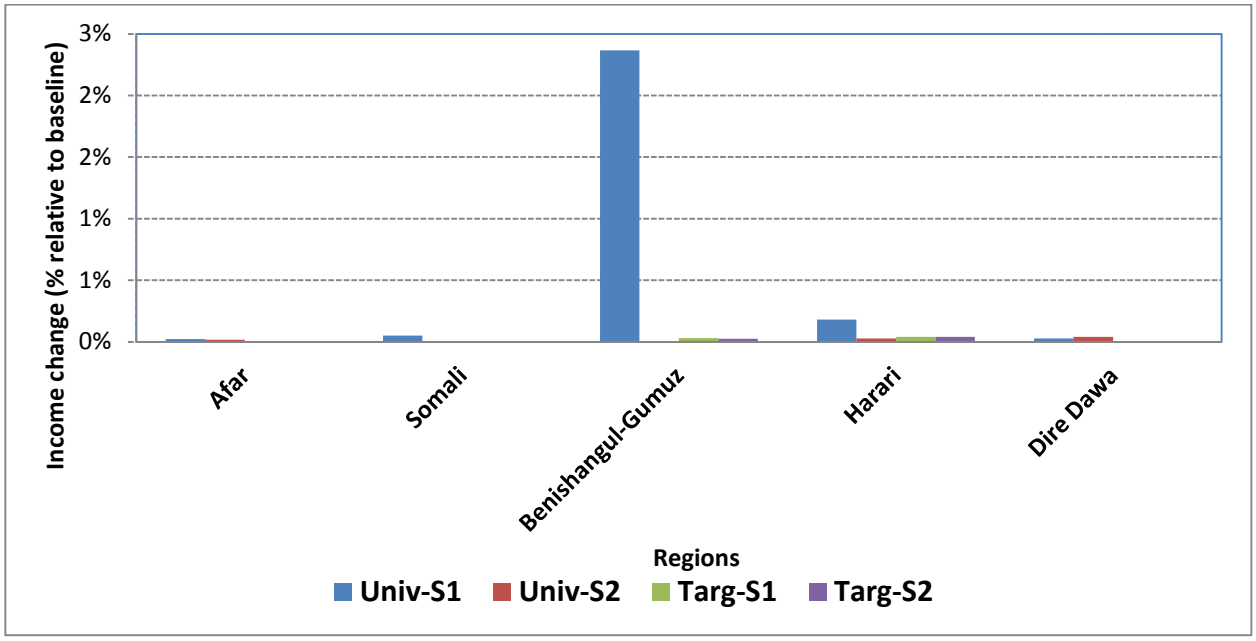
Under the simulated scenarios, the proportion of farms using fertiliser remains exactly the same as in the baseline meaning that none new smallholder farmers would start applying fertiliser under these conditions. This implies that producing with fertiliser is not profitable for these farms even with the subsidies. This can be explained by twofold reasons: first, the access to fertiliser is still difficult for these farms (i.e. high costs), despite the 50% price fertiliser reduction and second, the use of fertilizer and the resultant productivity in the selected regions are very low. It is important to recall that, in our simulation, all farm households could use fertiliser and their decision whether to use or not is only based on economic considerations. This is achieved using the following assumption: the gross margin of the non-observed activities during the base year is equal to the region average gross margin, the activity's quadratic function parameter is equal to the activity's average quadratic function parameter within the region, and the linear term's quadratic function is derived from the difference between the gross margin and the dual values of constraints.

The proportion of reallocated area due to the different simulated scenarios is marginal and represents less than 0.05 % of the average farm size. The main staple crops that would gain from this reallocation are corn and Teff in detriment of fallow and other crops, but this is very marginal and for that reason it was not reported here. The impacts of simulated scenarios on production are also insignificant, questioning the use of such program for improving food availability and thus, food security under low use of fertilizer and the resultant low productivity.

Figure 2 reports the income effects of the simulated scenarios at regional level. The results show that the potential increase in income caused by the implementation of both targeted and universal programs is small. The overall income raise represents less than 1 % compared with the baseline (less than 2% in all cases). The largest increase in income is observed in Benishangul-Gumuz under Univ-S1 scenario (i.e. 50% reduction of fertiliser price for all the farms and without any volume limitation). This is, however, not surprising since this region contains the largest number of fertiliser users and, therefore, potential beneficiaries of the programs.

The introduction of quota system limiting the volume of subsidised fertiliser to 50 kg per individual farm (Univ-S2 and Targ-S2) would impact negatively the income, in comparison to the absence of quota, but reduce the disparities between the target and universal programs.

Figure 2. Income effect of the fertiliser subsidy programs by regions (% change relative to baseline)



The aggregate impacts reported in Figure 2 may hide sizeable effects for individual farms. To gain further insight, Figure 3 shows the distribution of the percentage change in farm income relative to the baseline for all sampled farms (i.e. the total number of farms in the five regions is equal to 100). This figure is constructed by sorting, in ascending order, all of the farm

households according to the size of the income change until all farms (100 %) are reported. As shown in this figure, only a small proportion of farm households is positively affected by the simulated scenarios. Nevertheless, for a small number of farm households the income effect could be more substantial (more than +50%) which may improve their access to food. Although the income change of some farm households is substantial, the total proportion of farm households affected by the fertiliser subsidy represents only around 15 % of the total farm population in the five regions. Thus, about 85 % of the farm population is not affected at all because fertiliser use is too low for rational profit maximising farmers in these regions.

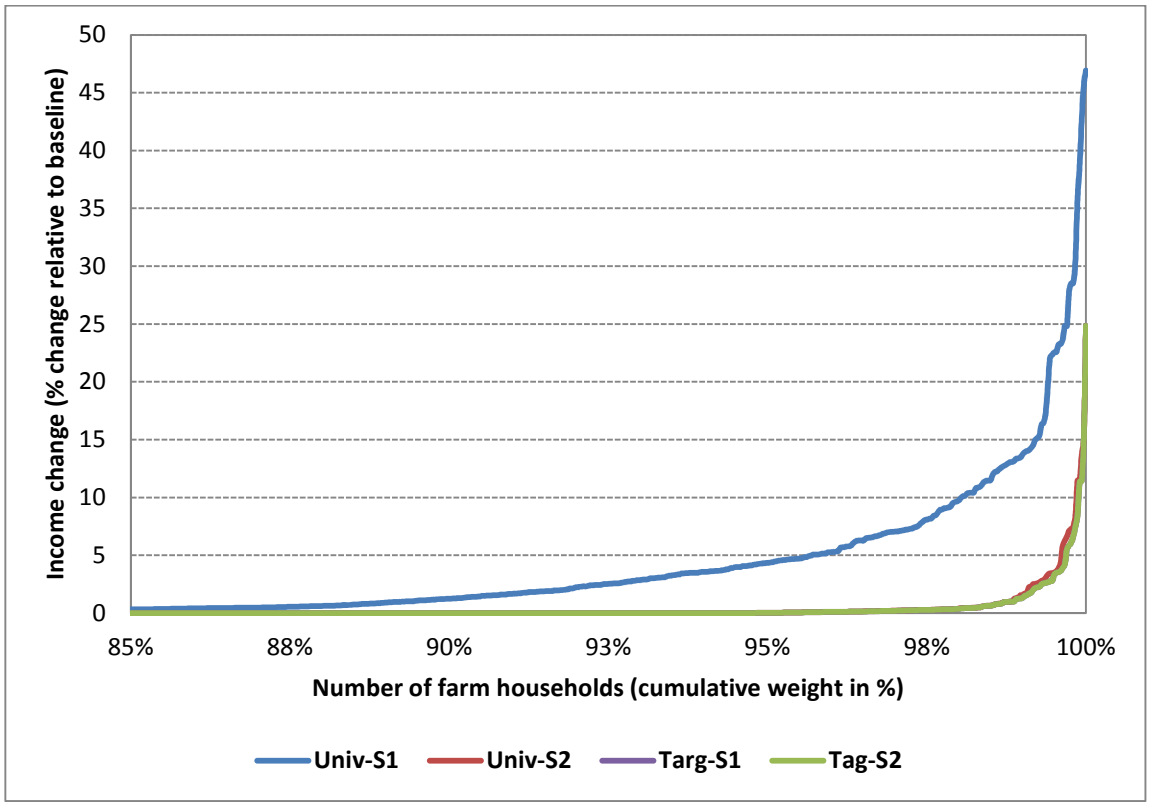


Figure 3. The distribution of the income change for the simulated scenarios by individual farm households (all sampled farms, % change relative to baseline)

4. Conclusion

This paper attempted to *ex-ante* assesses the impacts of two examples of fertilizer subsidy programs (targeted and universal programs) on the livelihood of smallholder farms in Ethiopia and on their food security. This is performed using a farm household model relying on positive mathematical programming model, FSSIM-Dev (Farm System Simulator for Developing Countries). FSSIM-Dev is applied at individual farm household level using a sample of 3979 smallholder farmers drawn from the AgSS survey for the cropping season 2014/2015. This modelling approach allows capturing the full heterogeneity across farm households and provides very detailed results, including average and distributional effects.

From a policy perspective, the main finding of this model application is the limited effect of the simulated fertiliser subsidy programs on crop area and production. The crop allocation

and production would almost remain the same as in the baseline; questioning the use of such programs for improving food availability under low use of fertilizer and the resultant low productivity. The income effect is also limited: agricultural income at aggregated level would increase by less than 1% in most cases. However, at individual level the impact would be more pronounced (reaching 40% in some farms) which may lead to an improvement of food access and, thus, food security. Although the income change of some farm housholds is substantial, the total proportion of farms affected by the fertiliser subsidy represents only around 15 % of the total farm population in these regions. This means that fertiliser use is too low for rational profit maximising farmers.

These findings have to be considered, however, with some caution on account of the model's assumption. First of all, output prices are assumed to be exogenously given. This implies that the market feedback (output price changes) is not taken into account in the model, while this effect tends to be important in developing countries. Therefore, our model will probably overestimate the overall effects of the simulated scenario. Another important limitation to our approach is the non-modelling of farm household consumption decision which is crucial in agriculture's Developing Countries due to its dependency with production and labour decisions. Further development of the FSSIM-Dev model will better take into account the above-mentioned limitations.

Despite these limitations, the simulation results presented here can be useful to policy makers that are currently designing input subsidy programs in Sub-Saharan African countries for food security purpose. To our knowledge, this is one of the few papers simulating the distributional effects of fertilizer programs across the farm household population.

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