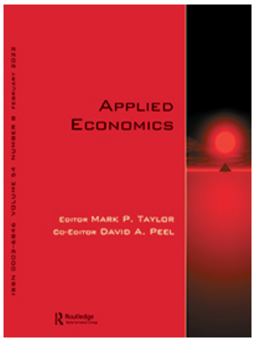

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Effectiveness of fertilizer policy reforms to enhance food security in Kenya: a macro–micro simulation analysis

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ABSTRACT

Food security represents a key challenge in most Sub-Saharan African countries and in Kenya in particular where still a relevant share of the population lives below a minimum dietary energy consumption. Kenya addresses this concern with a noteworthy policy mix, aiming at giving to the agricultural sector a leading task in improving food security. This paper evaluates the impacts on food security of expanding fertilizer capacities in Kenya, combined with a set of additional policy changes targeting fertilizer use. In a top-down analysis, a specific Computable General Equilibrium (CGE) model is linked with a microsimulation approach. Scenarios present overall positive effects on key food security aggregates. The same is true for welfare. Nevertheless, the heterogeneity of households across and within regions suggests that improving input productivity through better market access and service extension are critical to reducing possible discrepancies across farmers, households and regions. The paper concludes on the need for a sound policy mix since increasing fertilizer production alone is not enough to enhance food security evenly. Among accompanying measures, intensifying extension services are essential especially for smallholders in their acquisition of better knowledge on the use of agricultural inputs.

KEYWORDS

Agriculture; fertilizer; food security; Kenya; top-down simulations

JEL CLASSIFICATION

C68; Q18; O13; R20

I. Introduction

Food security, according to the most widely quoted definition, is achieved, "*at the individual, household, national, regional and global levels when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life*" (FAO 1996: action, 1). This definition also recognizes the high relevance for food security of sustainable agriculture, fisheries, forestry and rural development and the need to promote national and regional food security policies, to secure staple food supplies in developing countries.

In Kenya, over 2 million people receive food aid annually although agriculture is the backbone of Kenya's economy (USAID 2020). On average, over the period 2016–2018, the prevalence of undernourished in the total Kenya population is about 30%. The share of food-insecure households is as high as 68% in some regions of Kenya (Mutea et al. 2019). In absolute terms, the number of undernourished Kenyan people increased from 10.2 million in 2004–2006 to 14.6 million in 2016–2018 (FAO, IFAD, UNICEF, WFP & WHO 2019).[1] Kenya has historically been dependent on food imports even though agriculture contributes 30% of the GDP, around 65% of the exports and employs almost 80% of the labour force (KNBS 2015a). Cereals, vegetable fats and oilseeds significantly rely on imports. About 80% of the Kenyan households are net maize buyers (Levin and Vimefall 2015). Urban households are specifically vulnerable to food insecurity (Musyoka et al. 2014). Climate change is putting further pressure on agricultural production and food Security (Kogo, Kumar, and Koech 2020), threatening the livelihoods of the poorest. Last but not least, the COVID-19 crisis is

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[1]'*Undernourishment is defined as the condition of an individual whose habitual food consumption is insufficient to provide, on average, the amount of dietary energy required to maintain a normal, active, healthy life*' (FAO, IFAD, UNICEF, WFP & WHO 2019, 148).

expected to worsen the food insecurity significantly in most sub-Saharan African countries (Djiofack, Dudu, and Zeufack 2020) by limiting imports of intermediate inputs, among other effects.

One of the most critical drivers of low agricultural productivity is the lagging use of modern inputs, especially fertilizers, and the lack of access to technology (Mutea, Rist, and Jacobi 2020). Traditionally, Kenya attempted to solve the issue through public input subsidy programmes. However, the review of recent evidence questioned the effectiveness of this public support (Jayne et al. 2013). As a result, the Kenyan government is studying alternative approaches to price subsidies in order to increase the ability of all farmers to purchase the right inputs at the right time. The government is proposing a complete restructuring of the current subsidy schemes over the period of 2019–2029 (Government of Kenya 2019). In this context of sustainable agricultural transformation, it has facilitated the establishment of two fertilizer plants through Public–Private Partnership (PPP) projects. At the same time, various actions aim at improving the benefits of using fertilizers such as the development of extension programmes (Jayne et al. 2013). The aim of these policies is to increase food supply through higher productivity and ultimately improve food security and welfare. In particular, producing fertilizers domestically should not only boost domestic production but also reduce import dependency, limit the high costs of transportation, especially to upland regions as logistical problems at the port of Mombasa still raise the cost of fertilizers, further hindering effective demand increase (Ariga and Jayne 2011).

To the best of our knowledge, there is no economy-wide assessment of impacts on the economy, on food security and household welfare of the establishment of fertilizer plants in Kenya. The scope of the paper is to fill this gap analysing the impacts on both fertilizer and agricultural markets (production, prices, imports), on food security (food availability and affordability) and welfare in Kenya. To provide a comprehensive assessment, a set of accompanying policies (reduction in subsidies, improvement of market access and extension services) is simulated to complement the building of the fertilizer plants.

This paper uses an original dataset and a macro-micro modelling framework to perform the analysis. It corresponds to the first top-down linkage approach applied to the food security situation in Kenya. A tailored Computable General Equilibrium (CGE) model is linked with a microsimulation model based on the Kenya Integrated Households Budget Survey (KIHBS) 2005/2006. The CGE model accounts for specificities of the Kenyan economy such as high rates of subsistence and smallholder farming, the multi-output structure of production and migration. The model is calibrated to a 2014 Social Accounting Matrix (SAM), which includes subsistence and smallholder farming and whose agricultural sectors follow a regional disaggregation based on agro-ecological zones (AEZ) classification. Linking CGE with microsimulation model allows decomposing the effects of food affordability, consumption and income from the overall welfare change.

The rest of the paper is organized as follows: Section 2 introduces the main policy issues related to the development of the agricultural sector in Kenya. Section 3 presents the methodological approach of macro–micro simulations. Section 4 describes the database (SAM and household survey of Kenya). Section 5 describes the scenarios and analyses the results focusing on fertilizer and agricultural markets, food security and welfare. Finally, section 6 provides some concluding remarks and policy recommendations.

II. Kenya current situation for agriculture productivity and food access

In 2008, the Kenyan government launched 'Kenya Vision 2030', a strategy to transform Kenya into a middle-income country. The transformation of agriculture into a modern and commercially oriented sector is a strategic objective to achieve a targeted 10% annual growth rate (Government of Kenya 2007). In 2019, an Agricultural Sector Growth and Transformation Strategy (ASGTS) over the period 2019–2029 has been released (Government of Kenya 2019).

Low productivity is a challenge for the Kenyan agriculture, in particular in arid and semi-arid areas, which cover about 80% of the land. Kenyan farmers face multiple challenges hindering agricultural productivity (high post-harvest losses and diseases, land constraints, inadequacy of rural infrastructure, poor access to agricultural information), while central and local governments struggle with a limited budget (FAO 2014, 2015).

Productivity-enhancing inputs such as chemical fertilizers, improved seeds and pesticides are crucial to enhance agricultural productivity. Thus, a vital objective of the Kenyan agricultural policy is to expand their use, especially among smallholder farmers (Morris et al. 2007; Schroeder et al. 2013). The liberalization of fertilizer markets in the 1990s has fostered its use although still concentrated in most favoured agro-ecological regions (Ariga, Jayne, and Nyoro 2006). Fertilizer use increased by more than 50% between 2000 and 2010 while fertilizer use per hectare of arable land continued to grow at a rate of 73% between 2010 and 2013 (World Bank 2017; Ariga and Jayne 2011). A price drop by almost 50% between 1990 and 2007 has contributed to the increased use by farmers. Even after the price increase in 2008, due to the upsurge in world prices, prices remained lower than pre-1995 (Ariga and Jayne 2011). Since 2007, the Kenyan government subsidized fertilizers with the National Accelerated Agricultural Inputs Access Programme (NAAIAP).[2] Although subsidies increased fertilizer use (Mason et al. 2017), they started to become a significant financial burden (Sheahan, Ariga, and Jayne 2016) as the government spends almost €27 million every year on support programmes. The increase in fertilizer use relied mostly on imports (Ariga and Jayne 2011). Transporting imported fertilizers is time-consuming and costly (around 40% of the price) and part of the subsidy pays transport from abroad.

Despite all reforms, according to the Tegemeo Rural Household Survey farmers using fertilizers vary between more than 90% of the farmers in highlands and around 10% in coastal lowlands (with an intensity varying between 100 kg and 10 kg per acre). The same variability is observed among crops, with cash crop users and intensity much higher compared to maize farmers. These data show that still major impediments to the use of fertilizers such as constraints on financing the purchases, risk aversion of small-scale farmers, low returns to input use and the lack of information services (Mathenge 2016). Financial and physical fertilizers' accessibility remains an issue in many rural Kenyan areas. Most of the farmers are not using fertilizers because it is unaffordable. There is also a clear pattern indicating that consistent non-users of fertilizers are those more distant from sellers, extension agents or main roads. Besides, imported fertilizers are not always suitable for the local soil or crop type, leading to potential acidification of farmland and reduction of potential harvests.

The crucial requisites to increase the sustainability of input and fertilizer use are a more stable marketing environment, increased private sector participation to enhance input availability locally, the reduction of the distance to the dealers, increase of information and technical training, and the improvement of road infrastructure to decrease costs of transportation (Ariga and Jayne 2011).

Promoting domestic fertilizer manufacturing is becoming crucial. The government is committed to reducing fertilizer costs to improve availability and affordability, including the building of two factories. Consequently, the government has launched a roughly €1.1 billion fertilizer plant to be constructed in Eldoret in the framework of the fertilizer cost reduction strategy (Andae, 2015). This plant is supposed to blend a specific type of fertilizer suited for Kenyan soil and crops, and produce 150,000 tons of fertilizers (AFAP 2016). Furthermore, another factory of about €0.9 million is under construction in Nakuru by the private sector. These two factories have a combined capacity of 350,000 tonnes of production that would cover about 70% of the current fertilizer use in Kenya.

Reducing fertilizers' domestic price should boost their use (particularly for smallholders), account the need for local soils and varieties, contribute to increase food supply through higher productivity, and improve food security. Eventually, this could also eliminate the need for fertilizer subsidies, relieving the government budget from a significant burden. Lastly, it would decrease dependency on imports and reduce Kenyan vulnerability to fluctuations in international markets.

Against this background, empiric evidence from CGE analysis for Kenya suggests that fertilizer

[2]For a detailed description of the NAAIAP, results and challenges, see Jayne et al. (2013) and Mason et al. (2017).

strategy should be accompanied by improvement in rural infrastructures (i.e. roads) and extension services to reap the benefits of increased supply and reduced price of fertilizers (Thurlow, Kiringai, and Gautam 2007; Mabiso, Pauw, and Benin 2012; Sahoo, Shiferaw, and Gbegbelegbe 2016).

III. Modelling framework: a top–down simulation approach

Proper modelling of agriculture and food security issues in Kenya requires accounting for features and stylized facts that characterize its economy. This study adopts two approaches in a top-down sequence as in Chen and Ravallion (2004). It combines a CGE model calibrated to a 2014 SAM for Kenya and microsimulation techniques using households' data from the Kenya Integrated Households Budget Survey (KIHBS) 2005/2006 (KNBS 2007). Figure 1 provides a graphical overview of the methodology. First, policy scenarios are simulated with the CGE model. The changes in prices and factors' remunerations from these simulations are taken as inputs in the microsimulation approach. Then, using the households' consumption baskets and income composition from the survey data, the model assesses the consumption and income effects at the household level. Finally, non-parametric regressions of those effects provide the changes in welfare distribution across households given their location (rural/urban, AEZ) and quintile of income.

Similar techniques have been applied to assess the effects of agricultural policy reforms and technological changes on food security in selected African countries such as Ethiopia (Beyene et al. 2016), Malawi and Tanzania (Pauw, Thurlow, and Ecker 2018). To the best of our knowledge, no model in the literature has incorporated all these features when performing policy analysis in Kenya. The only existing top-down application applies to water management and water policy implications (Beyene et al. 2018). This paper contributes to overcoming this gap with a top–down simulation approach.

The top: a CGE model for Kenya

The CGE model is a comparative static variant of the STatic Applied General Equilibrium model (STAGE) (McDonald 2007, 2015) and its extension for the context of developing countries (STAGE-DEV) (Aragie et al. 2017).

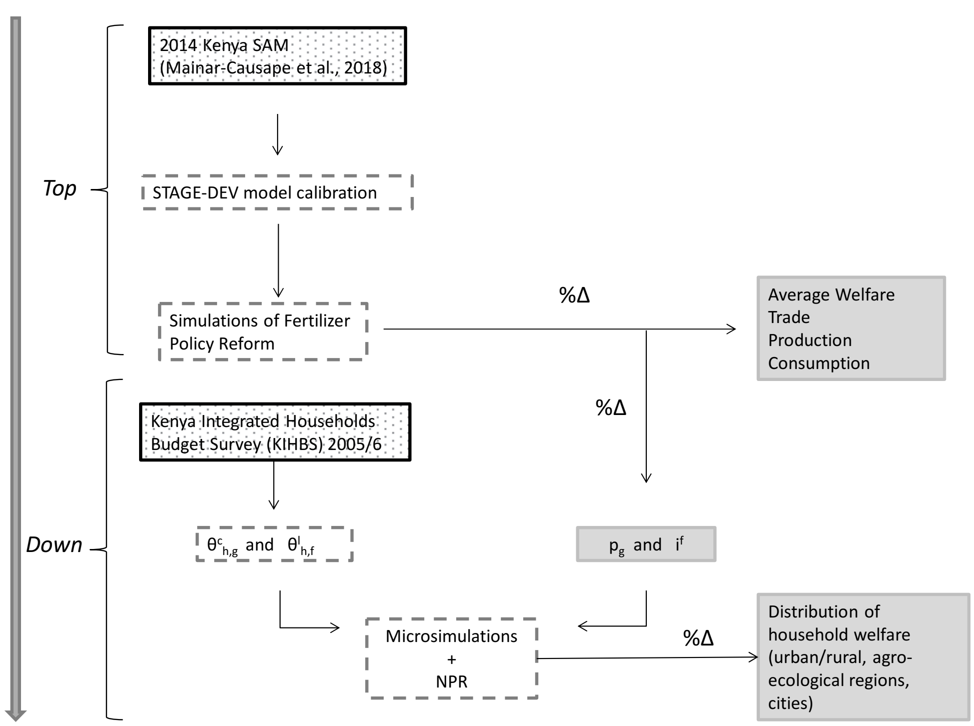

Figure 1. SCHEME OF THE TOP-DOWN SEQUENCE OF THE SIMULATION. Source: Own elaboration.

Implemented within the Joint Research Centre (JRC), the variant of STAGE-DEV accounts for the non-separability of the dual roles of smallholders as producers and consumers. Subsistence farmers produce their Home Production for Home Consumption (HPHC) allocating labour and capital for own consumption (and not to other uses). Modelling HPHC involves expanding the structure of a SAM including extra commodities valued at basic prices (excluding margins and sale taxes) while marketed commodities are valued at purchaser/market prices (including margins and sale taxes). Explicitly modelling household production, consumption and factor supply requires adjusting factor supply and market clearing conditions at the household level. This constrains the factor used in the own production activity through factor endowment. Smallholder producers are modelled as multiple-output producers with the composition of output varying in response to changes in relative prices of commodities through a Constant Elasticity of Transformation (CET) function (Punt 2013). Furthermore, the CGE model assumes household domestic migration within the country (driven by regional differences in incomes). The functional distribution of income changes as households migrate and transfer their respective factors (capital and labour). Importantly only economic incentives are embodied within the behavioural assumption (Aragie et al. 2017).

The model adopts a flexible production function for agricultural activities, assuming imperfect substitution between intermediate inputs, labour, capital and land composites (Constant Elasticity of Substitution (CES) function). Intermediate inputs (including seeds) display a perfect complementarity nesting using a Leontief production function. For seeds, at a lower level nest, household-produced and commercial seeds (i.e. bought from market) are imperfect substitutes assuming a CES function nesting. Different types of labour (i.e. skilled, semiskilled and unskilled) and capital (i.e. agricultural capital and livestock) are imperfect substitutes (CES nesting), allowing producers to switch to less expensive labour or more productive labour or capital types. The land composite allows imperfect substitution (CES function) between rain-fed land and a composite that combines irrigated land, water and fertilizers as substitutes (CES function).

Factors are fully employed, except the labour for which a constant rate of unemployment is assumed. The fixed supply of labour holds at national level while the regional supply is updated to reflect changes due to migration. Land is mobile across agricultural activities within each region.

Macroeconomic closure rules allow for a realistic description of the Kenyan economy. The exchange rate adjusts to keep the foreign savings at the base year level and avoid any additional creation of liabilities. Government savings are fixed and government spending adjusts to accommodate the change in government income. All changes are expressed in terms of the *numéraire*, which is the Producer Price Index (PPI).

The down: the microsimulation approach

Welfare results from the CGE model provide an average impact for each representative household according to its location (i.e. cities, urban and rural regions). However, within each location, households are heterogeneous according to their consumption preferences and sources of income, and thus, the distributive impact of welfare differs from the average. To enlarge the welfare analysis to the distributive effects across households, the CGE model is linked with a microsimulation module through the change in prices of products and factors remunerations.

Following existing literature on microsimulation (Deaton (1989a, 1989b, 1997) and Singh, Squire, and Strauss (1986)), especially applied to trade and agriculture reforms on households' welfare (Nicita 2009; Nicita, Olarreaga, and Porto 2014; Porto 2006), the paper assumes that the characteristics of each household, as consumer, producer and supplier of other production factors are mixed. Thus, policy changes affect the welfare of each group differently.

The compensated variation (cv_h) for each household (h) under each simulated scenario is computed approximating this measure as the difference between the income effect (i_h) and the consumption effect (p_h):

$$cv_h = i_h - p_h$$

The income effect corresponds to the percentage change in the household's income as the change in each factor's remuneration (i_f) weighted by the income shares ($\theta^I_{f,h}$) of the sources of income for each household:

$$i_h = \sum_f \theta^I_{f,h} * i_f$$

The consumption effect is calculated as the percentage change in the household's expenditure as the change in the prices of each commodity (p_g) consumed by each household weighted by its expenditure shares of each item ($\theta^C_{g,h}$):

$$p_h = \sum_g \theta^C_{g,h} * p_g$$

Once computed the three previous effects at the household level, non-parametric regressions between each of those effects and the logarithm of the per capita income/expenditure are performed.

IV. Calibration datasets

Calibration represents a critical process. Core data for the CGE model come from a 2014 SAM for Kenya with a highly desegregated agricultural sector and an original regional approach. For the micro part, household surveys, more specifically the Kenya Integrated Household Budget Survey (KIHBS) 2005/06, are key figures.

The social accounting matrix

A SAM for Kenya with base year 2014 (Mainar-Causapé et al. 2018) is estimated with specific accounts for the treatment of HPHC, and a regionalization based on agro-economic zoning and social characteristics. Table A1 in appendix shows a macro version of the SAM. This matrix is consistent with latest national statistics and is estimated from national accounts (KNBS 2015a, 2015b) and micro-data from the KIHBS 2005/06 (KNBS 2007). Other databases related to agriculture (Government of Kenya 2015) and labour markets (KNBS 2015a, 2015b) are employed to update the production structure while previous SAMs (Kiringai, Thurlow, and Wanjala 2006; Thurlow, Kiringai, and Gautam 2007) are used as auxiliary databases.

The 2014 SAM for Kenya deviates from standard matrices with the introduction of HPHC. The classic Representative Household Groups (RHG), which gather household behaviour as consumers of goods and services and as providers of factors of production, show the behaviour of households as units of production of commodities. These accounts incorporate the economic behaviour of households as producers of food commodities (agricultural and livestock products) as well as cash crops. This requires separate accounts for commodities produced by these households for own consumption (HPHC as input or as a final product) and other marketed commodities (produced by households and by conventional productive activities). Table A2 in appendix lists the commodity and activity disaggregation in the SAM.

Kenya is split into six agro-ecological zones (AEZ) plus two largest metropolises, i.e. Nairobi and Mombasa. Based on previous studies (Mabiso, Pauw, and Benin 2012; Kiringai, Thurlow, and Wanjala 2006), the AEZs (High rainfall, Semi-arid North, Semi-arid South, Coast, Arid North, and Arid South) reflect different production characteristics and cost structures (Figure 2). The regional breakdown applies to households as productive and institutional units. Households as institutions are further disaggregated into rural and urban, according to the area of residence. Furthermore, in both Nairobi and Mombasa, households are disaggregated by quintiles of income.

The households survey

To estimate the welfare effects in Kenya at the household level, robust data from household surveys are crucial. KIHBS 2005/2006 is one of the core databases in the construction of the SAM (i.e. RHG, aggregation of consumed commodities) and is essential for the microanalysis. Table 1 shows the correspondence for the regions, sectors, factors and households between the Kenya SAM 2014 used to calibrate the CGE model and the survey used to run microsimulations.

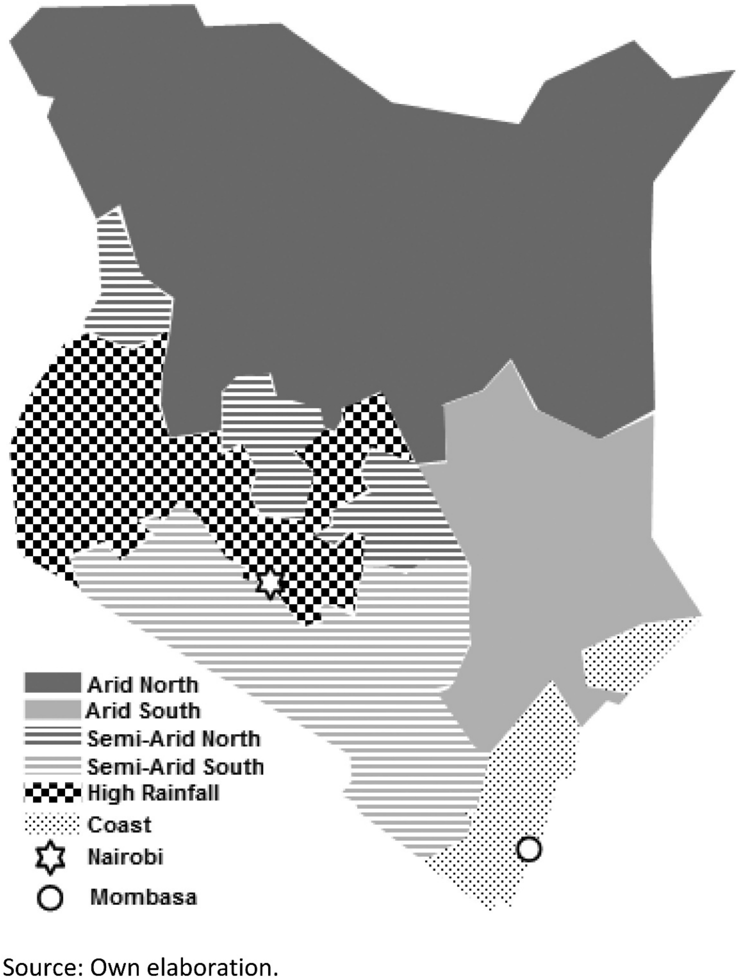

Figure 2. KENYA AGRO-ECOLOGICAL ZONES. Source: Own elaboration.

Table 1. DATA CORRESPONDENCE BETWEEN THE 2014 SAM AND THE 2005/2006 KIHBS FOR MACRO-MICRO SIMULATIONS.

	CGE model	HH survey
Regions	**r = 8** 2 cities 6 AEZ	**69** districts
Consumed commodities	**c = 50** 20 agri-products 3 extractive (fishing, forestry and mining) 14 manufactured goods including food 13 services	**531** consumption items
Income sources	**f = 35** **27** labours (3 skills * 8 r + RoW) **2** lands (irrigated, non-irrigated) **2** capital (agri, non-agri) **1** livestock	 **63** KNOCS (4 dig.) **2** accounts (land and subsoil rents) external regional data for irrigation net benefits **118** ISIC Rev.3 (4 dig.) + 5 (1 dig.) - other sources (transfers, res/com rents, etc.)
Households	**h = 24** Q5 in cities, RU/UR in agro-eco regions	13,212 households (original) after treatment **11,802** households

Source: Own elaboration.

The correspondence of different levels of disaggregation allows computing the shares of income sources and the shares of expenditure by goods and services.

For labour income data from the survey, the Kenya National Occupational Classification Standard (KNOCS) is used to match the skill-based labour of the SAM. To address missing values of labour income for some households, an average hourly wage by occupation type for all households with a positive number of worked hours is used. A similar procedure is applied for capital income at the household level. The annual positive net benefits received by all members of each household is employed, differentiating agricultural and non-agricultural capital in view with the type of activities according to the International Standard Industrial Classification of All Economic Activities (ISIC Rev 3).

For the calculation of land income at the household level, the annual rentals from land and subsoils assets are used, since the land factor is only used in agriculture in the CGE model. Then, those land incomes are classified in irrigated and non-irrigated lands according to their percentages in each AEZ. Annual rentals from residential, commercial and other properties are grouped in other income sources such as transfers.

These calculations of each source of income compatible between the SAM and the survey are used to compute income shares at the household level. Expenditure of goods and services given the household consumption data follows a similar procedure. When data are incomplete (positive quantities but no spending), the expenditure by item is estimated with consumed quantities per household and the computed unit value (based on the value of purchase or the average). The expenditure shares are thus calculated for 50 products and services from the SAM based on the 531 items consumed according to the survey.

After treatments mentioned above to calculate the consumption and income shares at the household level compatible with the SAM disaggregation, the microanalysis considers 11,802 complete individual observations (90%) from the initial sample of 13,212 observations.

V. Simulation results

The methodology presented initially quantifies the stylized impacts of the investment in the new fertilizer plants only, and then in combination with further agricultural policy reforms. This section describes the simulated scenarios and comments key results on fertilizer and agricultural markets, food security and households' welfare in Kenya.

Scenarios' Design

The models quantify the stylized impacts of the construction of fertilizer plants *(Fertilizer)* as the central scenario, and three additional policy options *(Subsidies, Market* and *Extension)*.

According to the 2014 SAM for Kenya, the domestic production of fertilizers covers 30% of the Kenyan consumption, i.e. 150 thousand tons (Ariga and Jayne 2011; Mainar-Causapé et al. 2018). In the central scenario *(Fertilizer)* the investment in the fertilizer sector allows doubling the domestic production. For this purpose, the model simulates an investment increase of Ksh 5.15 billion in this sector that approximately equals the amortization of investment in the additional fertilizer factories (i.e. 5% of the Ksh 103 billion). The new investment increases the physical capital stock of fertilizer production sector. The exchange rate adjusts to keep the current account in balance. The government amends the income tax to keep the saving-investment balance in the economy and to raise the amount needed to subsidy the new investment.[3]

Three policy options are simulated on top of the central scenario.

1Removing Subsidies (Subsidies): Government of Kenya employs input subsidy programmes to subsidize fertilizers. These programmes represent a financial burden on public finance of almost €27 million yearly, despite being suitable to increase the use of fertilizer. Increasing the domestic production of fertilizers can undoubtedly reduce the price of fertilizers. Lower prices might

[3]The choice of the closure avoid the creation of 'free-lunch' situation that would boost positive economic returns unrealistically. Thus, government has to account for the cost to subsidy the capital formation and to maintain the equilibrium of the account fixing the amount of public saving. The best replacement tax strategy is to let the income tax on households endogenous to keep the equilibrium. In this model, income tax are lump sum taxes so they do not bias any economic choice of the agents in the model.

also reduce the need for subsidies. Under this scenario we sum to the fertilizer scenario (doubling domestic production) the removal of the subsidies on fertilizers.

2.Better Market Access (Market): Most farmers cannot have access to fertilizers because of poor infrastructure such as road networks (Raballand, Macchi, and Petracco 2010). This is reflected in fertilizers' prices with high trade margins (Key, de Janvry, and Sadoulet 2000). Under this scenario, the domestic trade and transport margins fall by 30% in exchange for a further increase in investments of Ksh 4 billion to improve infrastructure, financed by government savings. Trade margins of agricultural products also decrease by 30%, as their delivery would become cheaper. The magnitude of the shock looks larger than in similar applications (Arndt et al. 2000) but plausible given the amount of the investment planned and the size of current trade margins in the country. Moreover, the elasticities estimated by Benin et al. (2008) support the size of this shock.

3.Extension Services (Extension): Better extension services can be vital in improving food security (Njura, Kaberia, and Taaliu 2020). More conscious use of fertilizers and seeds is essential outcomes of expanding extension services. The impact of better extension services is simulated by improving the productivity of fertilizers and seeds by 5% and agricultural labour by 3%. The elasticities used for these productivity improvements are in line with those estimated by Benin et al. (2008). The productivity gains require an increase in public spending targeting extension services.[4] The annual cost of reaching one farmer is Ksh 520 (Muyanga and Jayne 2006), the extension services reach 7.5 million households with a cost of Ksh 4 billion. This amount, financed by the government (public savings), is added to the investments on top of the amortization cost of the factories.

Impact on markets

Results of the *Fertilizer* scenario are presented in comparison with the baseline (*status quo*) while the results of the other three scenarios are presented in comparison with the central *Fertilizer* scenario.

Fertilizer markets

Doubling the production of fertilizer (*Fertilizer* scenario) decreases the supply price by around 20% (Table 2) which differs from the targeted price decline of 40% defined by the government of Kenya (Andae, 2015). Under additional scenarios, changes in supply prices are negligible. Imported fertilizers still dominate the domestic market consumption under all scenarios.[5] Furthermore, there is a limited transmission of lower fertilizers' prices into market prices of agricultural products (Table 7).

The decline in domestic prices under the central scenario generates an increase in fertilizers' exports close to 6% of the production. This appears to be below the targeted amount, which is due to the rise in domestic demand. Demand for imports does not decline. The additional fertilizer production partially accommodates the domestic demand leaving

Table 2. FERTILIZER PRODUCTION, CONSUMPTION, PRICE AND TRADE.

	Base	Fertilizer	*% change from fertilizer scenario*		
	billion Ksh	*% change from base*	Subsidy	Market	Extension
Production	7.82	100	−4.7	7.5	2.0
Consumption	26.45	37.5	−7.5	3.5	5.4
Supply Price	1	−21.6	−1.8	1.0	1.2
Purchaser Price	1.04	−7.6	−0.6	−0.6	0.4
Export	0.27	223.7	−1.0	1.1	0.6
Import	18.9	17.4	−8.8	4.0	6.4
Exports/Production (%)	3.5	5.7	5.9	5.6	5.6
Import/Consumption (%)	71.5	61.0	60.2	61.3	61.2

Source: Model results.

[4]It is not necessary to include a specific activity in the SAM to analyse the effects of improving extension services. Indeed, there are contemplated through economic relationships (mainly elasticities) and changes in public spending on activities potentially benefiting from this scenario.

[5]Under other Armington elasticity assumptions (multiplied by 2, 3 and 5), imports still dominate (57%, 54%, 51% respectively against 60% of consumption). Even in the casa of perfect substitutes, imports are still at 44%. One can assume that key factor is not linked Armington assumption but rather to the structure of the sector.

Table 3. FERTILIZER USE BY TYPE OF FARMERS.

	Base	Fertilizer	% change from fertilizer scenario		
	billion Ksh	% change from base	Subsidy	Market	Extension
Smallholder	15.61	36.4	−14.5	4.0	9.5
Export Oriented	4.23	41.0	2.0	0.3	0.6
Market Oriented	6.62	38.1	2.5	4.4	−1.2
Total	26.45	37.5	−7.5	3.5	5.4

Source: Model results.

a very low margin for exports. It leaves Kenya still relying on imported fertilizers.

Removal of subsidies (*Subsidy* scenario) pushes up fertilizer prices discouraging their use and thus, leading to an adverse effect on supply from both domestic production of fertilizers and imports with decreases by −4.7% and −8.8%, respectively (Table 2).

Furthermore, improving market access and extension services increases fertilizer production by 7.5% and 2%, respectively (Table 2). The main difference between these two scenarios is reflected in trade outcomes. Boosting market access due to better infrastructure increases imports and consumption less compared to expanding extension services. Indeed, in the latter, the rise in demand is mainly supplied by higher imports, even under a high trade margin environment. In contrast, as trade margins for fertilizers decline, demand increase is provided by higher domestic production showing the importance of market access in the fertilizer sector.

Farmers' use of fertilizer increases under all scenarios, showing an average increase of about 37% under the central scenario compared to the baseline (Table 3). However, removing subsidizes (*Subsidy* scenario) discourages the use of fertilizers by smallholders, who currently benefit from the subsidy policy. In contrast, extension policies (*Extension* scenario) are beneficial for smallholders by improving the use of fertilizers because of the acquisition of better knowledge on the use of agricultural inputs. Better access to fertilizers through improved infrastructure (*Market* scenario) increases the use of fertilizers by all farmers.

Agricultural markets

The greater availability of fertilizers (*Fertilizer* scenario) benefits commercial agricultural producers (Tables 4 and 5) in particular coffee, tea, tobacco and sugar producers and exporters from the high rainfall and semi-arid regions, which display the highest share of fertilizers use in the base year (2014). Smallholder farmers benefit very little from the doubling of fertilizer production since their fertilizers use is low in the base year.

Under the *Market* scenario, production of smallholder farmers increases the most, showing

Table 4. AGRI-FOOD PRODUCTION BY SECTORS.

		Base	Fertilizer	% change from fertilizer scenario		
		billion Ksh	% change from base	Subsidy	Market	Extension
Total	Agri-Food	2,363.21	0.67	−0.17	0.37	1.14
	Food	642.13	0.10	−0.07	0.46	0.62
	Agriculture	1,721.08	0.88	−0.21	0.34	1.33
	Livestock	388.10	0.15	−0.13	0.49	1.15
	Crop	1,332.98	1.09	−0.23	0.29	1.38
	Export Crops	328.40	3.78	−0.56	−2.89	2.39
	Food Staples	1,004.58	0.21	−0.11	1.37	1.04
HPHC	Agri-Food	300.41	0.18	−0.17	0.93	1.50
	Food	11.12	0.09	−0.09	1.17	1.62
	Agriculture	289.30	0.18	−0.17	0.92	1.49
	Livestock	69.95	0.14	−0.16	1.43	2.01
	Crop	219.35	0.19	−0.18	0.76	1.32
	Food Staples	219.35	0.19	−0.18	0.76	1.32
Marketed	Agri-Food	2,062.79	0.74	−0.17	0.29	1.09
	Food	631.01	0.10	−0.07	0.44	0.60
	Agriculture	1,431.78	1.02	−0.21	0.22	1.30
	Livestock	318.15	0.15	−0.13	0.28	0.96
	Crop	1,113.63	1.27	−0.24	0.20	1.39
	Export Crops	328.40	3.78	−0.56	−2.89	2.39
	Food Staples	785.23	0.22	−0.10	1.54	0.96

Source: Model results.

Table 5. PRODUCTION BY REGIONS AND ACTIVITY TYPE.

		Base		Fertilizer		Subsidy		Market		Extension	
		billion Ksh		*% change from base*		*% change from fertilizer scenario*					
		Market	HPHC	Market	HPHC	Market	HPHC	Market	HPHC	Market	HPHC
Small Holder	Nairobi	12.85	2.68	−0.3	−0.4	0.1	0.4	0.4	0.7	−0.6	−0.4
	Mombasa	4.73	1.34	0.0	0.0	0.0	0.0	−0.4	−0.7	0.2	0.0
	High rainfall	695.37	199.21	0.2	0.2	−0.2	−0.2	0.8	0.8	1.3	1.3
	Semi-arid North	106.35	33.61	0.2	0.2	−0.2	−0.2	0.6	0.5	1.0	1.0
	Semi-arid South	94.21	44.59	0.1	0.1	−0.2	−0.2	2.4	2.3	2.7	2.6
	Coastal	113.2	11.61	0.2	0.2	−0.2	−0.2	0.2	0.3	0.8	0.7
	Arid North	12.7	5.83	0.2	0.2	−0.2	−0.2	−0.4	−0.3	3.1	3.1
	Arid South	5.37	11.04	0.2	0.2	−0.2	−0.2	0.9	1.1	2.2	2.3
Export Oriented	High rainfall	151.32		3.98		−0.6		−3.4		2.5	
	Semi-arid North	44.63		3.72		−0.6		−3.2		2.4	
	Semi-arid South	1.78		3.37		−0.5		−2.7		2.7	
MarketOriented	Food Crops	201.24		0.31		0.1		2.9		−0.4	
	Cotton	0.35		−2.86		0.0		2.9		−2.9	
	Sugar	6.36		3.30		−0.6		−3.0		2.4	
	Coffee	7.3		5.21		−0.5		−3.3		2.3	
	Tea	99.93		3.93		−0.6		−3.6		2.6	
	Tobacco	1.82		3.85		−0.5		−3.2		2.1	
	Other Crops	14.91		0.60		0.1		8.0		−0.1	
	Livestock	48.64		0.00		0.0		−1.1		−0.3	
	Dairy	23.28		0.00		0.0		−0.6		0.1	

Source: Model results.

positive effects on the availability aspects of food security. However, all export-oriented production decreases as well as most of marketed-oriented production. Tea and sugar are the most negatively affected crops, compensated by the production of other crops (mostly composed of cut flowers) with an additional 8% increase by contrast to the central scenario. Vegetables, rice, root and tubers are the commodities whose production increases the most.[6] The underlying reason for these increases is the higher production of marketed products rather than the production for home consumption as expected. However, the greater availability of food staples for home consumption also increases, indicating the importance of complementary policies for addressing food security issues.

Export crop producers and smallholder farmers increase their production under the *Extension* scenario, because of technological change. The difference between *Market* and *Extension* scenario points out the importance of a (need for) breaking the backward technology trap. The *Market* scenario

Table 6. EXPORT AND IMPORTS.

		Base	Fertilizer	*% change from fertilizer scenario*		
		billion Ksh	*% change from base*	Subsidy	Market	Extension
Exports	AgroFood	377.3	3.2	−0.5	−2.3	−1.2
	Agriculture	349.1	3.4	−0.5	−2.3	−1.2
	Crops	348.1	3.4	−0.5	−2.6	−1.3
	Food Staples	34.9	0.2	−0.2	0.3	0.1
	Export Crops	313.2	3.8	−0.6	−2.9	−1.5
	Livestock	1.0	0.0	0.0	2.0	1.0
	Food	28.2	−0.1	−0.2	1.2	0.6
	Other	577.1	−0.3	−0.1	0.9	0.5
	Total	954.3	1.1	−0.2	−0.4	−0.2
Imports	AgroFood	243.1	0.4	0.0	0.9	0.5
	Agriculture	202.1	0.5	0.0	0.9	0.5
	Crops	201.0	0.5	0.0	1.2	0.6
	Food Staples	176.2	0.3	0.0	1.5	0.7
	Export Crops	24.8	1.8	−0.4	−0.8	−0.4
	Livestock	1.1	0.0	0.0	−0.9	−0.9
	Food	40.9	0.2	0.0	−0.3	−0.2
	Other	1,732.9	0.5	−0.1	−0.4	−0.2
	Total	1,976.0	0.5	−0.1	−0.2	−0.1

Source: Model results.

[6]Crop production results are excluded from tables for readability. Detailed results are available upon request.

Table 7. CONSUMER PRICE.

	Fertilizer		% change from fertilizer scenario					
	% change from base		Subsidy		Market		Extension	
	Marketed	HPHC	Marketed	HPHC	Marketed	HPHC	Marketed	HPHC
Agriculture	−0.07	−0.09	0.03	0.10	−0.83	0.04	−0.33	−0.82
Crop	−0.08	−0.07	0.02	0.08	−1.00	−0.42	−0.31	−0.96
Food Staples	−0.11		0.03		−1.01		−0.33	
Export Crops	−0.11		−0.02		0.03		−0.02	
Livestock	−0.06	−0.14	0.06	0.17	−0.30	1.19	−0.41	−0.59
Food	−0.08	−0.14	0.04	0.17	−0.68	1.28	−0.29	0.29

Source: Model results.

enables smallholder farmers to expand their activities at the cost of export crop producers due to the competition for factors: they become more competitive and able to use more of the factors in the economy. On the other hand, when a factor-saving technological change is introduced under the *Extension* scenario, the competition for factors is limited and both types of agricultural activities can expand.

Exports of agricultural commodities follow the production trend (Table 6). Under the *Fertilizer* scenario, exports expand as the production whereas the addition of policies partially erodes those gains, particularly for export crops. The results do not change much under the *Subsidy* scenario. Under the *Market* scenario, exports of the main staples (maize, wheat, root and tubers and rice) increase. However, exports of cash crops decline as production declines. Finally, under the *Extension* scenario, exports of traditional export crops are equal to the *Fertilizer* scenario while export crops decrease. These results argue on the necessity of improving trade-benefiting infrastructures as well as productivity in services such as logistics or customs.

Results suggest that the benefits of cumulated policies are mostly directed towards the domestic markets and will improve food security in terms of food availability. On the other hand, policies might harm the exports of cash crops as they increase the competitiveness of the smallholder farmers who are traditionally producers of food staples. Thus, to keep the positive impact of the increase in fertilizer availability on food exports, further measures are needed. Since the decline in exports is mostly due to the shift of economic resources towards smallholder production, which traditionally does not produce much export crops, measures that will help smallholder producers to switch to production of export crops can be a straightforward way to avoid agricultural export decline.

Under the simulated scenarios, agricultural sectors absorb more labour (Figure 3) with shifts more pronounced under the *Market* scenario and particularly the *Extension* scenario. Under the *Extension* scenario labour productivity increases, and skilled labour is the labour type whose employment in the agricultural sector increases the most. This indicates a possible shift towards a more modern agriculture and the influence of the extension services to the transformation of the agricultural sector.

Impact on households

To provide a sound welfare analysis and food access at national, regional and the household levels, the results shed some light on the changes in consumer prices of goods and factors' remunerations under every scenario.[7]

Investing in fertilizer plants (*Fertilizer* scenario) reduces consumer price slightly (Table 7) by decreasing production costs and increasing production. The most significant price reduction, thus improving in the affordability aspects of food security, is achieved by reducing trade and transportation margins via infrastructure investments (*Market* scenario) where the food staples price falls by more than 1% compared to the *Fertilizer* scenario.[8] The *Extension* scenario also

[7]This paper does not address economy-wide approach to price analysis or the linkages between policy measures, food availability and consumers' ability to acquire food at affordable prices. Kargbo (2000) shows how crucial these linkages are in designing and implementing successful food policy programmes.
[8]Results are in line with the findings of Sahoo, Shiferaw, and Gbegbelegbe (2016) which report a food prices drop by 0.6%, shocking trade and transportation margins by 15% for agri-food commodities, and without modelling costs of improved infrastructure.

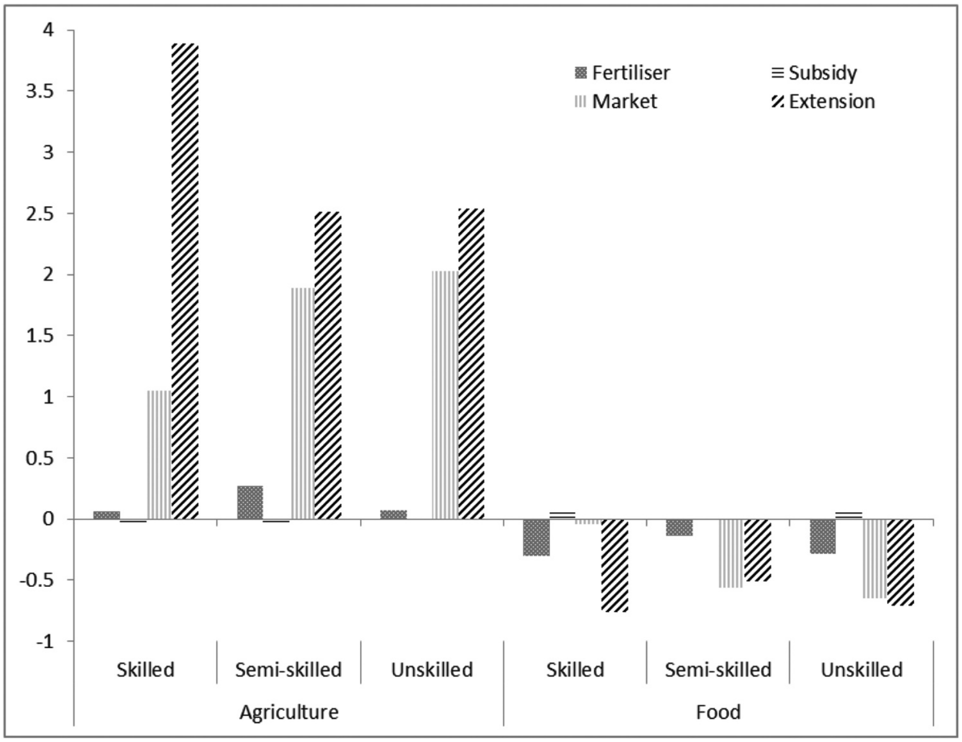

Figure 3. EMPLOYMENT BY MAIN SECTORS, % CHANGE FROM BASELINE. Source: Model results.

Table 8. RETURN TO FACTORS.

	Fertilizer	Subsidy	Market	Extension
	% change from base	*% change from fertilizer scenario*		
Irrigated Land	0.03	0.01	0.57	−0.15
Non-Irrigated Land	0.04	0.01	0.55	−0.14
Livestock	−0.05	0.03	0.33	−0.23
Agricultural Capital	0.14	−0.01	0.34	−0.04
Non-Agricultural Capital	0.09	−0.02	−0.13	0.14
Skilled Labour	0.10	0.00	−0.16	0.21
Semiskilled Labour	0.09	−0.01	−0.05	0.29
Unskilled Labour	0.11	−0.03	−0.09	0.23

Source: Model results.

intensifies the reduction in consumption prices but shows a lower and more homogeneous price decrease across products compared to the *Market* scenario.

On factors' remuneration, Table 8 shows a modest increase of agriculture-related returns to land and capital under the *Fertilizer* scenario, and more pronounced under the *Market* scenario. However, the latter displays a negative impact on labour wages for all type of skills because the returns on land and capital absorb most of the benefits associated with the reduction of margins. In contrast, the *Extension* scenario boosts labour productivity leading to the increase in wages in detriment of other factor remunerations.

Welfare results slightly differ between CGE and micro models because of models' assumptions and the differences in the data aggregation and calculations. The CGE model computes the Equivalent Variation (EV) for the representative household of each region under each scenario considering all direct and indirect effects of price and income changes. In contrast, the microsimulation model computes the welfare impact as the addition of income and consumption effects computed all at the individual household level with a further weighted aggregation. Nevertheless, the ranking of scenarios in terms of average welfare change remains consistent between models' results.

Greater availability of staples (*Fertilizer* scenario), and thus lower food prices, improve food access and welfare in Kenya but not uniformly across regions or households by percentiles of income (Table 9 and Figures 4, A1, 5, 6 and A2). Food becomes more affordable for households leading to a slight increase in the purchasing power on average, which is presented as a positive consumption effect due exclusively to the change in agri-food prices (Figures 4 and A1). The

Table 9. HOUSEHOLD WELFARE.

	Population*	Fertilizer	Subsidy	Market	Extension
	thousand people	*Ksh per capita*	*difference from fertilizer scenario (KSh)*		
Urban	5,641	347	23	−200	368
Nairobi and Mombasa	3,685	278	31	−249	149
Poorest 20% in cities	1,433	377	68	−467	115
Others in large cities	2,252	214	7	−111	170
Other Urban	1,957	477	8	−107	781
Arid	118	368	−18	305	670
High rainfall	1,437	517	5	−94	833
Semi-arid	401	364	23	−274	627
Rural	7,759	428	−34	313	952
Arid	498	112	−4	100	780
High rainfall	5,470	451	−33	229	812
Semi-arid	1,791	446	−44	628	1,429
Grand Total	13,400	394	−10	97	706

*Number of employed persons estimated by the model.
Source: Model results.

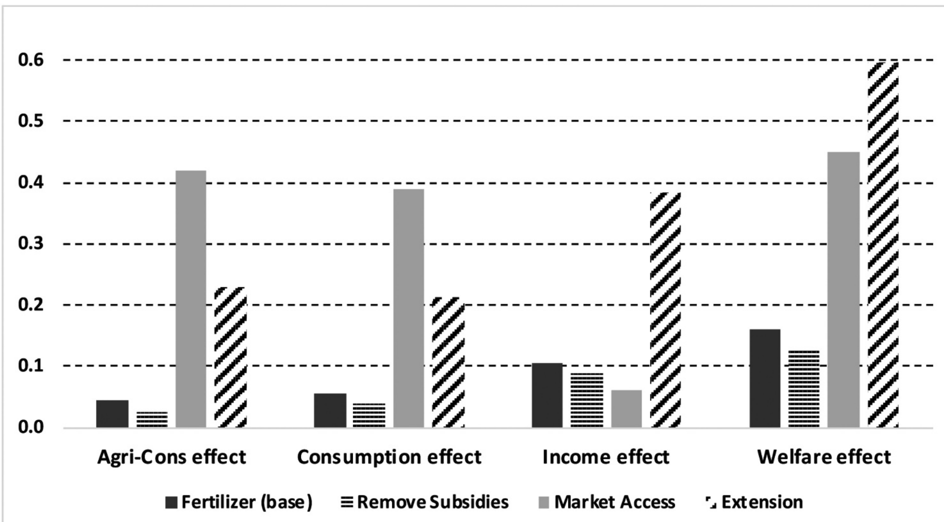

Figure 4. AGRI-FOOD AND OVERALL CONSUMPTION, INCOME AND WELFARE EFFECTS AT NATIONAL LEVEL. (Weighted average: 100 poorest percentile to 1 richest percentile) Source: Simulation results.

overall national welfare effect is mainly explained by the income effect (higher labour income gains), even when consumption and income effects are positive (Figures 4 and A1). Moreover, there is no remarkable change in the distribution of welfare gains across households at the national level (flat line) but, at the regional level, welfare gain distribution becomes pro-middle income households and pro-rich in most of the AEZ except in the semi-arid North zone where low-middle income households benefit relatively more (Figures 6 and A2, scenario *Fertilizer*).

Removing subsidies (*Subsidy* scenario) is the worst scenario in terms of average welfare change; however, CGE results show that welfare slightly increases in urban areas, particularly for most poor people in large cities. In Figures 6 and A2, scenario *Subsidy* shows that welfare gains are higher in Mombasa than Nairobi, even when welfare slightly improves everywhere. Under this scenario the poor located in the arid South zone is the most affected by the elimination of subsidies, while middle-income households living in the semi-arid North and the high rainfall zones benefit the most of this scenario. Moreover, this scenario deteriorates income distribution across households mainly in the arid South region.

Under the *Market* scenario, welfare increases at the national level. The results are pro-poor because of both income and consumption effects, with outstanding agri-food consumption effects (Figure 4 and A1). Moreover, comparing the welfare effect between urban and rural areas (Figure 5), gains intensify in the former with an unambiguous pro-poor welfare

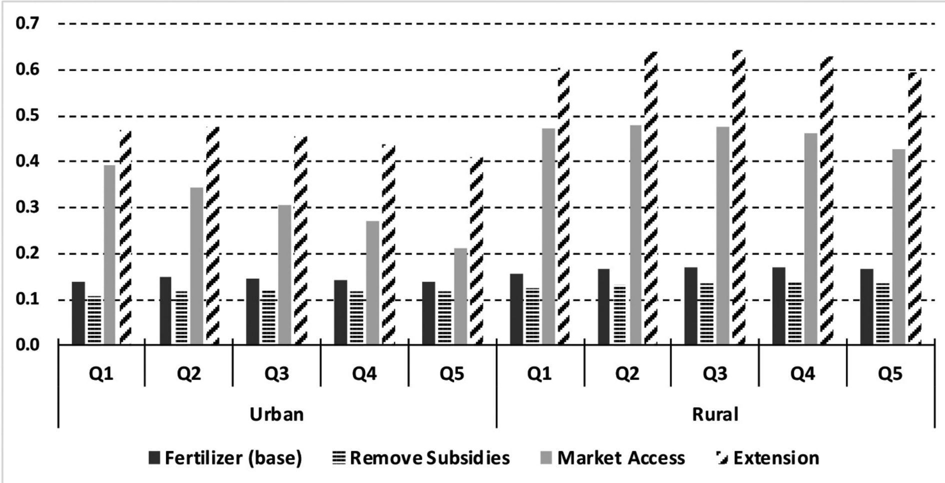

Figure 5. URBAN VS. RURAL WELFARE EFFECT ACROSS QUINTILES OF INCOME. Source: Simulation results.

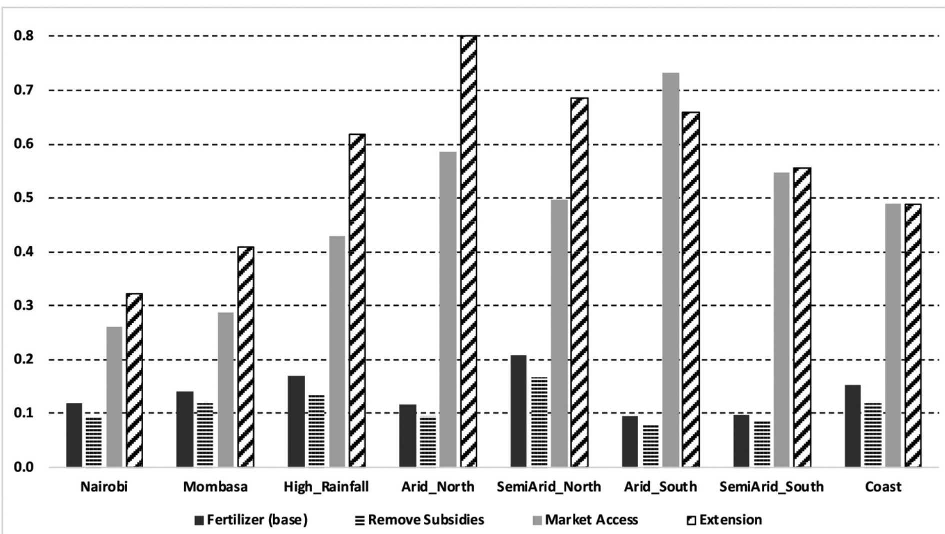

Figure 6. DISTRIBUTION OF THE WELFARE IMPACT ACROSS PERCENTILES AND AEZ. (Weighted average: 100 poorest percentile to 1 richest percentile) Source: Simulation results.

impact, since lower costs of distribution and trade facilitations relatively improve affordable food access. Looking at CGE results in Table 9 and Figures 6 and A2 (*Market* scenario), regions that benefit market access improvements the most are arid (North and South) and semi-arid (North). Comparatively, Mombasa and Nairobi display lower welfare variations, showing though a pro-poor welfare results.

As expected, the most significant welfare gains come from the *Extension* scenario (Table 9 and Figures 4 and A1). Even when welfare increases more in rural than urban areas because better agriculture techniques lead a more significant income effect, in urban areas the distribution of the welfare gains are pro-poor because of lower prices in the underlying basket of consumption (Figure 5). Arid North and South and semi-arid North benefit the most of the welfare gains on average but unevenly distributed, particularly in the arid South regions where the poor benefit the least (Figures 6 and A2).

Since these welfare results correspond to average regional impacts, it is crucial to better understand the distribution of welfare changes across households taking into account the composition of their consumption baskets and sources of income.

VI. Conclusions

Enhancing food security represents a key challenge for policy-makers in Kenya. In the international development agenda, this reflects a critical Sustainable Development Goal '*End hunger, achieve food security and improved nutrition and promote sustainable agriculture*' (SDG2) and inter-linkages especially with empowering small farmers or ending rural poverty. This paper assesses the effects of a policy mix expanding fertilizer capacities in Kenya with a set of additional measures. It uses an original methodology that combines a top-down approach with recent disaggregated data of the Kenyan economy and society.

Results suggest that doubling the fertilizer production benefits Kenyan agricultural sector mostly through the expansion of export crops, primary users of fertilizers. Thus, households producing export crops gain the most from the increasing fertilizer production while smallholder farmers scarcely benefit since their fertilizer use is lower. Furthermore, the eventual elimination of fertilizer subsidies would negatively affect smallholders who currently profit from this provision. It is therefore essential to target regionally and individually any change in public support.

Importantly, to improve food security and income of smallholders living in arid and semi-arid zones, Kenyan policy-makers should implement some accompanying policies such as increasing the market access for both input (fertilizer) and output (agricultural production). Improving rural infrastructure is critical, especially because lowering transport cost increases the consumption of vegetables, wheat, root and tubers, therefore improves both food availability and affordability. Expanding extension services to smallholders also appears central in disrupting the technology trap and raising income (welfare). Decreases in food prices benefit urban consumers the most whereas gains are unevenly distributed in rural areas, especially in the arid South regions where the poorest benefit the least. This calls for further measures targeting the multiple dimensions of poverty.

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Disclaimer

The views expressed in this paper are the sole responsibility of the authors and do not necessarily reflect those of the European Commission, the World Bank or any institution.

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Appendix

Table A1. KENYA SAM 2014 (ABBREVIATE VERSION). KSHS '000 MILLION.

	ch	cm	m	ahf	ahc	a	flab	fland	flivst	fcp_ag	fcp_na	hh	enter	gov	dirtax	indtax	saltax	facttax	imptax	i-s	row	Total
HPHC commodities (ch)				150.7								161.1								0.9		312.7
Marketed commodities (cm)			292.5	293.9	50.1	3,158.5						4,162.0		750.4						1,144.2	954.0	10,805.7
Margins (m)		292.5																				292.5
Households as activities food (ahf)	312.7	1,045.8																				1,358.5
Households as activities cash-crops (ahc)		197.7																				197.7
Activities (a)		7,087.1																				7,087.1
Labour factor (flab)				92.7	14.6	1,545.9															15.9	1,669.2
Land factor (fland)				536.2	113.7	206.8																856.7
Livestock (flivst)				141.2		33.6																174.7
Capital agricultural (fcp_ag)				98.7	19.3	77.3																195.3
Capital non-agricultural (fcp_na)				45.1		1,912.3																1,957.4
Households (hh)							1,600.2	856.1	174.7	195.2	455.4		1,048.5	41.6							324.3	4,696.0
Enterprises (enter)								0.3			1,501.0			505.4								2,006.7
Government (gov)															554.0	152.7	207.0	7.9	160.7		25.7	1,108.0
Direct taxes (dirtax)												311.6	242.4									554.0
Indirect taxes (indtax)						152.7																152.7
Sales taxes (saltax)		207.0																				207.0
Factor taxes (facttax)							6.6	0.3	0.1	0.1	0.9											7.9
Imports taxes (imptax)		160.7																				160.7
Save/Investment (i-s)												51.3	715.8	−213.9							592.0	1,145.1
Rest of the World (row)		1,815.0					62.4					9.9		24.5								1,911.9
Total	312.7	10,805.7	292.5	1,358.5	197.7	7,087.1	1,669.2	856.7	174.7	195.3	1,957.4	4,696.0	2,006.7	1,108.0	554.0	152.7	207.0	7.9	160.7	1,145.1	1,911.9	

Note: Rows of commodity accounts reflect HPHCs use as intermediate inputs in the productive activities of households and their consumption in final demand of households (RHG). The columns of each commodity account summarize the production of these commodities by each household activity. Similarly, columns of the households activities show how they use inputs (HPHC and marketed), while rows show the destination of their production as inputs, own-consumption goods or marketed commodities.

Source: Mainar-Causapé et al. (2018).

Table A2. KENYA SAM 2014 ACTIVITIES AND COMMODITIES.

HPHC commodities	Marketed commodities	Representative Households Groups as activities	Activities
Maize	Maize	***Food***	Food crops
Wheat	Wheat	Nairobi	Cotton
Rice	Rice	Mombasa	Sugarcane
Other cereals	Other cereals	High rainfall	Coffee
Roots and tubers	Roots and tubers	Semi-arid North	Tea
Pulses and oil seeds	Pulses and oil seeds	Semi-arid South	Tobacco
Fruits	Fruits	Coast	Others crops
Vegetables	Vegetables	Arid North	Livestock
Beef	Cotton	Arid South	Dairy
Dairy	Sugarcane		Fishing
Poultry	Coffee		Forestry
Sheep, goat …	Tea	***Cash crops***	Mining
Other livestock	Tobacco	High rainfall	Meat and dairy
Fishing	Others crops	Semi-arid North	Grain milling
Sugar and bakery …	Beef	Semi-arid South	Sugar and bakery …
Beverages and tobacco	Dairy		Beverages and tobacco
Other manufactured food	Poultry		Other manufactured food
Water	Sheep, goat …		Textile and clothing
	Other livestock		Leather and footwear
	Fishing		Wood and paper
	Forestry		Printing and publishing
	Mining		Petroleum
	Meat and dairy		Chemicals
	Grain milling		Fertilizers Nitrogen
	Sugar and bakery …		Fertilizers Phosphorus
	Beverages & tobacco		Fertilizers Potassium
	Other manufactured food		Metals and machines
	Textile and clothing		Non-metallic products
	Leather and footwear		Other manufactures
	Wood and paper		Water
	Printing and publishing		Electricity
	Petroleum		Construction
	Chemicals		Trade
	Fertilizers Nitrogen		Hotels
	Fertilizers Phosphorus		Transport
	Fertilizers Potassium		Communication
	Metals and machines		Finance
	Non-metallic products		Real estate
	Other manufactures		Other services
	Water		Administration
	Electricity		Health
	Construction (Roads)		Education
	Construction (Irrigation)		
	Construction (Other infrastructures)		
	Construction (Others)		
	Trade		
	Hotels		
	Transport		
	Communication		
	Finance		
	Real estate		
	Other services		
	Administration		
	Health		
	Education		

Source: Mainar-Causapé et al. (2018)

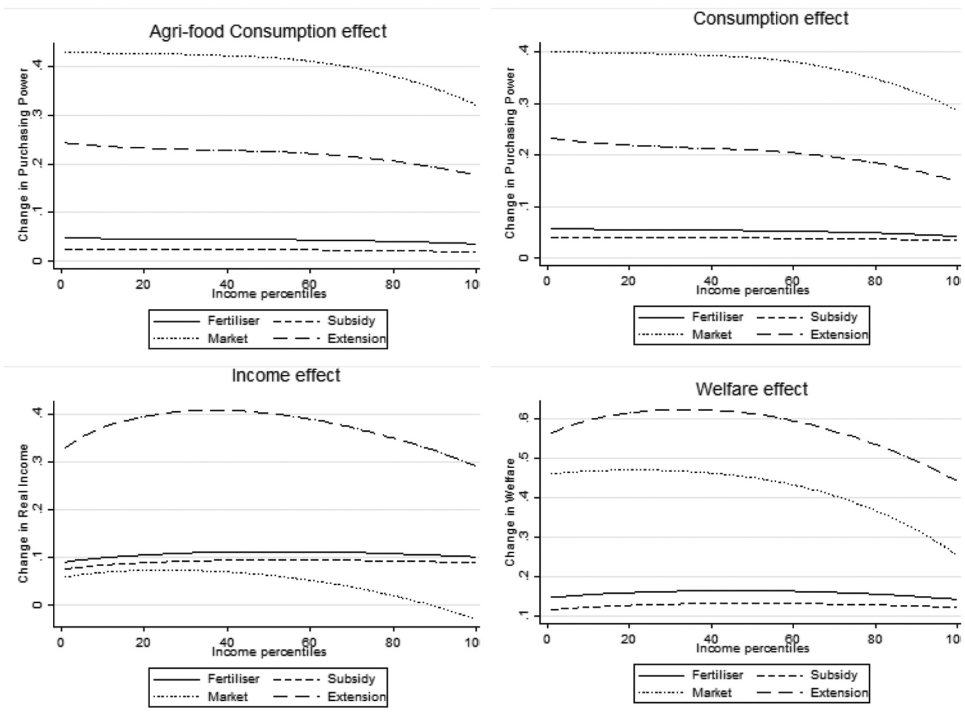

Figure A1. AGRI-FOOD AND OVERALL CONSUMPTION, INCOME AND WELFARE EFFECTS AT NATIONAL LEVEL. Source: Simulation results.

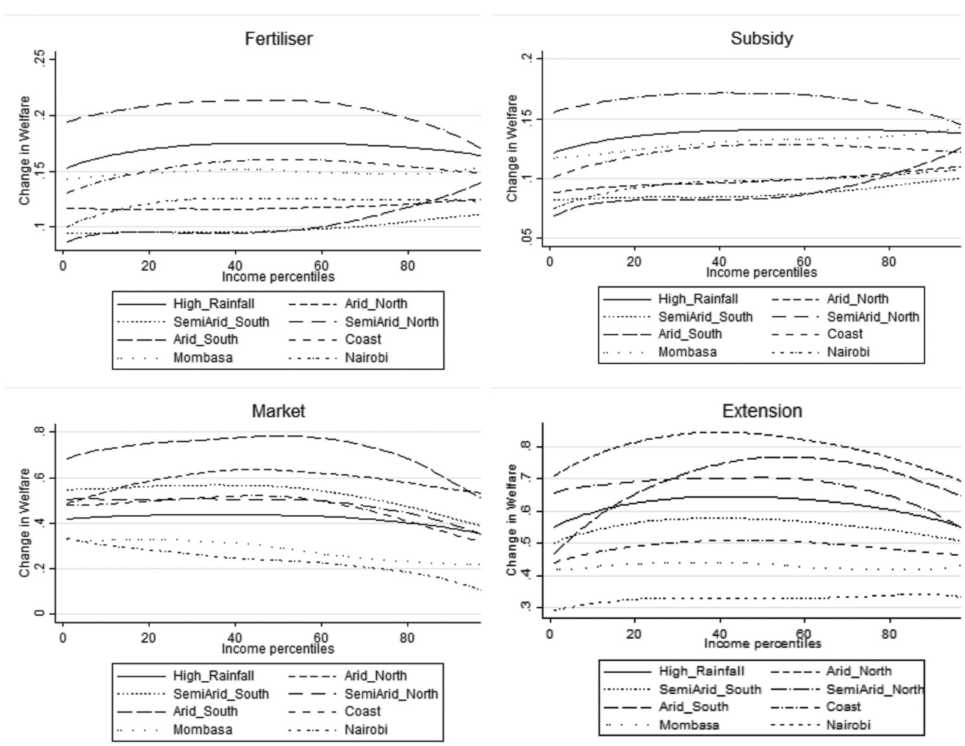

Figure A2. DISTRIBUTION OF THE WELFARE IMPACT ACROSS PERCENTILES AND AEZ. Source: Simulation results