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Economywide impacts of promising agricultural technologies on food security and welfare in Kenya

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1. Introduction

Agriculture has been the main source of livelihood for almost 80% of the rural population in Kenya. However, almost half of the country's population still lives below the poverty line (KNBS, 2008). Food production has not kept pace with the increasing population pressure, which has led to food insecurity in the country, especially in the arid and semi-arid regions of the country. The Strategy to Revitalize Agriculture (SRA) and Kenya Vision Maize 2030 have emphasized the importance of enhancing agricultural productivity and marketing systems to overcome food insecurity and poverty. While introduction of promising crop technologies is expected to increase agricultural productivity through higher yields, decrease in trade and transport margins by way of better marketing systems, improved transport and rural infrastructural development can also induce higher agricultural production and enhanced food security.

Traditionally, agricultural growth in Africa is achieved by cultivating more land, but there has been very little improvement in yields and barely any change in production techniques (NEPAD, 2013). Maize is the major staple food in Kenya, accounting for about 63% of total cereal caloric intake, followed by wheat, accounting about 24% total cereal (FAOSTAT, 2011). Though average yields of aggregate cereals have increased from 1196 kg/ha in 1991-2000 to 1386 kg/ha in 2001-2013, mainly because of increased yield of wheat, yields of other cereals have remained stagnant since 2000 (FAOSTAT, 2013). The average maize yield slightly dropped from 1654 kg/ha in 1991-2000 to 1636 kg/ha in 2001-2013. This is partly due to reduction of investment in agricultural research and development (Please and Thirtle, 2009). Moreover, Kenyan agriculture remains primarily rainfed, adding to the uncertainty in crop productivity.

In addition to technological change, many studies in sub-Saharan Africa have found that improved road accessibility to agricultural extension as well as rural road networks can have significant impacts on farm productivity and poverty reduction (Dorosh et al., 2012; Dercon et al., 2007). The findings by Kiprono and Matsumoto (2014) using longitudinal and a geo-referenced roads data indicated that road improvement could alleviate poverty in Kenya though through increased productivity and market participation of smallholder farmers. Using a sample Kenyan maize growing households, Renkow et al. (2004) using an econometric approach measured the size of fixed transaction faced by rural semi-subsistence households. They showed that on average the ad valorem tax equivalent of the fixed transaction costs for households in marketing maize was 15.5%, while buying prices of maize were on average was 35% above selling prices.

Findings from studies using CGE models for Kenya with its agro-ecological zones suggest that that increasing only agricultural spending is not sufficient to meet the higher agricultural growth target; additional investments like road development coupled with rural market development are required to foster stronger growth in agriculture and are also effective in reducing poverty amongst Kenya's poorest households (Thurlow et al., 2007; Mabisa et al., 2012). Results from a static computable general equilibrium model for Mozambique indicates that gains from combination of improved agricultural technology and lower marketing margins exceed the sum of gains from separate scenarios (Arndt et al., 2010). Our study investigates the long run food security and welfare impacts from the introduction of promising high yield potential and drought tolerant maize and wheat technologies, and the reduction of transport cost margin for these crops. The effects of these changes are investigated for households in different agro-ecological regions of Kenya.

A dynamic economy-wide computable general equilibrium (CGE) model with three ago-ecological regions is developed to evaluate the impacts of shifts in crop technology from the prevailing maize and wheat varieties to promising varieties adapted to different agro-ecological conditions in Kenya. The promising maize and wheat technologies used in our study include drought-tolerant and high-yielding varieties of these crops based on the Decision Support System for Agrotechnology Transfer (DSSAT) crop simulation and International Maize and Wheat Improvement Center (CIMMYT) studies for many African countries including Kenya. In addition, we evaluate the effect of technological change in conjunction with a reduction in transport margins on maize and wheat that induces market access of these staples. The main interest is to evaluate the economy-wide impacts of introducing the promising maize and wheat technologies along with the reduction in transport margins on the future scenarios for food security and well-being in Kenya to 2030.

The rest of the paper is organized into four sections. Section 2 outlines the database and the methodology, while baseline and alternative scenarios are discussed in Section 3. The results are presented and discussed in Section 4. Section 5 concludes the paper highlighting key policy issues.

2. Database and Methodology

Contribution of agricultural growth on household income, input and output prices, and indirect effects on other sectors are sometimes not systematically measured using a partial equilibrium approach. Though the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) which has spatial disaggregation for different regions and covers a range of agricultural production activities uses a system of supply and demand equations to analyze baseline and alternative scenarios, as a partial equilibrium model, it ignores economywide interlinkages. Calzadilla et al. (2013) uses a combination of IMPACT-Water partial equilibrium model and a global computable general equilibrium model to improve calibration for expected changes in total agricultural productivities under climate change, 0.5% in adaption scenario. compared to the baseline.

The CGE model used in our study is calibrated using data on projected rate of exogenous growth trends in productivity of maize and wheat based on IMPACT study. We use estimated yield differentials of existing varieties of maize and wheat for three agro-ecological regions from crop simulation model results for Kenya from DSSAT. As the focus of our study is on the impact of introducing promising varieties, we use more credible information, instead of assuming some hypothetical agricultural productivity improvement, from the crop simulation model results on the resulting productivity gains in the different agro-ecological region in Kenya.

The dynamic recursive CGE model solves sequentially for each period based on the economic behaviours and assumptions that link growth in one period to the next period till the year 2030. The model closely follows the single country dynamic PEP-1-t (Decaluwé et al., 2010) model, which assumes a multi-market and competitive economy. The benchmark dataset that describes the Kenyan economy is based on the 2007 SAM - Social Accounting Matrix (Thurlow et al., 2007; Thurlow et al., 2008; Mabiso et al., 2012).

The Kenya CGE model represents the structure of the economy in three agro-ecological regions: high rainfall, arid and semi-arid, with 25 commodities and 69 production activities across the three agrological regions. It includes 10 crops including maize and wheat produced by 28 regional crop activities. Each commodity can be produced by several regionally disaggregated production activities. However, we assume a single national product market for each crop.

Kenya's agro-ecological zones differ in many ways. Though highland and midland are almost equally populated, the share of highland's economy in terms of real GDP at factor cost is almost one and half time that of midland (Table A1). On the other hand, the sparsely populated lowland holds only 5% of the national GDP. About 70% of the economy's agriculture is produced by the highland and 25% by the midland. Highland shares about 80% of economy's maize and wheat production, while the midland contributes about 20% and 18% of respective crops. Livestock as a major source of income in lowlands share almost 22.5% of the economy's value of livestock.

Households are classified according to regions, rural, urban and five expenditure quintile categories. Households own the labour, land, livestock and capital as endowments. The highland households account for about 67% of the personal income. Land cultivated by the rural households in highlands accounts for almost 82% of the national cultivated land (Table A1). Compared to other regions, the consumption basket of the lowland rural households is dominated by the food items. While rural households in highland and midland spend more on food consumption, their urban counterparts spend more on the non-food consumption. Maize consumption is mostly a rural phenomenon and the wheat consumption is in fact negligible. Though the household consumption of wheat is low in Kenya, it is mostly used as intermediate input; wheat is also one of the highly importable crops in the economy (Table A2). It is worth noticing that the household expenditure on processed food constitutes a larger share in the food basket across the regions.

The intermediate inputs and value added are combined in a fixed proportion to produce one unit of output of a sector. The value added in a sector has a constant elasticity of substitution (CES) between labour and composite capital, which in turn is a CES combination of land, livestock and capital. Skilled, unskilled and semi-skilled labour is combined in a CES production function to constitute composite labour. Capital is sector-specific. Land is only used in the agriculture sector. In order to capture the net effect of the productivity change in maize or wheat, the land for these crops is assumed to be fixed. Similarly, land used for growing cash crops and fruits are generally fixed. Labour is mobile between sectors and within a region and is in excess supply, while land and capital are fully employed. The model incorporates unemployment in an efficiency wage framework.

Trade and transport margin is added to the domestic price of domestically produced as well as imported commodity in addition to the indirect taxes as it is passed on to the consumers as higher consumer price. The freight on board (FOB) export price in the world market includes the trade margin that differentiates the FOB export price from the price received by the producer that produces export goods. The composite price paid by consumers is the weighted sum of domestic and import prices.

For imports, world prices are given and on the export side, given the price of the competing exports and demand from the rest of the world, there is an inverse relationship between volume of exports and export price. Exported and imported goods are differentiated from the domestically produced goods. The balance of payment constraint incorporates fixed foreign savings in dollar terms, which equals net exports plus net foreign transfers, all in dollar terms. The exchange rate of domestic currency is determined by the market.

In the dynamic scenario, investment creates new capital for specific sectors. The volume of new capital investment is linked to the level of existing stock in business sectors[1] and the elasticity of investment with respect to the ratio between return to capital and user cost (Lemelin and Decaluwé, 2007). The user cost of capital depends on the price of new capital, the rate of depreciation, and the interest rate. Volume of new capital investments to public

[1] Activities in our model are classified into public sectors and private (business) sectors.

sectors is fixed.

1. Scenarios

The study aims to evaluate the outcomes and prospects for food security in the long run to 2030 resulting from introduction of new promising maize and wheat varieties as well as potential improvements in marketing systems. The impact of technological and market improvements are analysed under alternative scenarios in order to understand the individual and combined effects of different interventions. The following scenarios are developed for our analysis.

a. Baseline scenario

The baseline scenario in our analysis considers constant growth rate of the economy as well as exogenous productivity trend of maize and wheat without promising technologies over the period 2007 and 2030. All the exogenous variables except prices follow the population growth rate of 2.7% annually. Baseline scenario also considers productivity differentials for each ago-ecological region.

The exogenous growth rates of harvested area and yield for different crops based on the base-year 2000 till 2050 are adopted from IMPACT (Rosegrant et al, 2012). The baseline productivity rates for maize and wheat are determined based on this information. The DSSAT crop simulation model estimates by CIMMYT provided the information on maize and wheat yields in high rainfall, arid and semi-arid regions, which are assumed to remain unchanged as climate change impacts are not included in this analysis. The maize and wheat productivity changes associated with the three agro-ecological regions for our base year 2007 and baseline productivity growth rates till 2030 are computed using the IMPACT model exogenous growth rates and DSSAT simulations specific to the three agro-ecological regions (Table 1). In the baseline simulation, the zone-based yield differentials of maize and wheat for different zones are applied based on the DSSAT crop model.

b. Technological change Scenarios

This includes total factor productivity changes in maize and wheat production due the introduction of promising varieties. New promising technology is introduced in the year 2015 and continues to 2030 assuming no climate change. The promising varieties would increase yield and hence, total factor productivity over existing varieties (based on DSSAT simulation).

Current challenges to maize production in tropical Africa mainly consist of deficient soils, drought stress, and stresses from pests and diseases. However, CIMMYT, IITA, and their partners are developing high-yielding maize germplasm well-adapted to the stresses affecting tropical maize. In recent years, multiple improved drought-tolerant varieties have been released in several African countries with support from the DTMA project (Abate et al., 2015; Abate et al., 2013a; Abate et al., 2014; Abate et al., 2013b; Obeng-Antwi et al., 2013).

The DTMASS project launched in 2014 targets seed sectors, aims to facilitate access to certified drought-tolerant maize varieties for small scale farmers in seven countries in eastern and southern Africa. Recent controlled field trials imply that drought-tolerant maize varieties would bring yield gains varying between 20.5% and 40.6% for the maize grown in lowlands. The yield advantage from drought-tolerant maize varieties grown in mid-altitude areas would vary between 3.5% and 23% (Yoseph Beyene, personal communication). Hence, the yield gain from drought-tolerant maize in controlled environment can be translated into gains varying between 3.19% and 6.32% for maize grown in mid-altitude areas in Kenya. For maize grown in lowland areas, the yield gains from drought-tolerant maize would vary between 1.25% and 8.21%.

This study assesses promising technologies which are in the pipeline of being released to farmers in Kenya. The improved maize varieties for highlands in Kenya would have a high-yielding trait. Mid-altitude and lowland zones are more prone to drought and hence improved maize varieties targeted for these zones would combine high-yielding and drought tolerance traits. The yield gain should be higher in the highland zone compared to the other zones; based on the experimental field data, the yield gain varies between 4.28% in the lowland zone to 5% in the highland zone (Table 1).

Wheat production in Kenya is mainly hindered by biotic stress such as rusts and septoria (Shiferaw et al., 2013); in the lowland and mid-altitude zones, wheat is also affected by drought stress. Promising wheat technologies which are assessed in this study involve varieties that are both high-yielding and drought-tolerant. The yield gain from promising wheat varieties varies between 2.92% in the lowland zone to 3.02% in the highland zone (Table 1). In our model we assume that the yield gains due to improved varieties of maize wheat remain unchanged over the period.

The technology change scenarios are:

- **Scenario 1**: Increase in maize productivity due to improved varieties
- **Scenario 2**: Increase in wheat productivity due to improved varieties
- **Scenario 3:** Increase in joint productivity of maize and wheat

c. Marketing costs scenario

We add a reduction of trade and transport margins for maize and wheat on top of productivity changes from promising technologies. While productivity change increases supply, reduction in transport margins reduces the cost of intermediate input as well as prices on final consumption by households. The trade and transport margins could be interpreted as cost of marketing the product from the suppliers to the consumers or storage, which are borne by the buyers. These are introduced in the model as marketing service coefficients. Reduction in this margin for maize and wheat as the targeted market facilitation lowering the cost of access to market would to lead to reduction in the purchase prices of these crops to both consumers and producers. According to Ariga and Jayne (2009) among other factors, a decline in the distance travelled by farmers to the point of maize sale, reflecting improved functioning of maize assembly has contributed to growth in smallholder farm income and welfare in Kenya.

Our benchmark data in SAM 2007 shows that 'trade and transport' margins of maize and wheat are about 7% and 8% of the market value for these crops. We simulate the same proportional reduction in transport margins across all three agro-ecologies. We assume that maize or wheat produced in different regions faces a uniform average transport margin (per unit market supply) irrespective of ago-ecological regions. A study by Kirimi et al (2010) finds that spatial margins between surplus and deficit regions are low; wholesale prices in surplus areas are in the range of 90-95% of prices in the deficit regions. Hence, in our scenario, we ignore this 5-10% price differences between surplus (highland and midland) regions and deficit (midland) regions. We simulate a 15% reduction in the marketing margin on both maize and wheat while simultaneously maintaining the productivity increase for the two crops[2].

Scenario 4:

- 15% reduction of trade and transport margin for maize and wheat with increase in productivity of maize and wheat as in scenario 3

2. Results

As indicated above three promising crop technology scenarios are introduced to quantify the impacts of promising maize and wheat varieties on future food security and wellbeing of households in Kenya. In addition, a combined scenario of productivity increase along with a reduction of transport margins for these crops is simulated. The results from these alternative simulations are expressed in terms of percentage changes from the baseline in 2030.

Scenario 1: maize productivity change

Introduction of high yielding and drought tolerant maize varieties directly increases the output of maize, increasing its production by 1.23%, 1.01% and 0.61% for the midland, lowland and highland regions, respectively (Table 2). The positive spill-over output effects of are observed in case of other crops activities in highlands. Maize accounts for about 36% of total value of food production and 17% of the total value of cultivated area in the base year[3].

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[2] It is assumed that investment on technology and marketing infrastructure has already been made at the time of simulation.

[3] Computation based on the Kenya Social Accounting Matrix.

Given the importance of this crop in terms of its contribution to Kenya's food production and its land engagement, the impact of increased maize productivity is expected to be bigger on the agricultural sectors.

With increased productivity, production of maize becomes less resource intensive generating a downward pressure on factor income. Rents to land in maize production in highland, lowland and midland regions declines significantly, -11.81%, -12.07% and -12.36%, respectively; rent to capital also declines by -5.51%, -6.21% and -6.15% for the same regions (Table 3). Rents to land decline for other sectors except for except for wheat. Though capital rent declines in maize activities, it has increased for other activities. Wages decline relatively less than the decline in rents to other factors (Table 3). An increase in maize production s significantly reduces the composite prices of maize by 3.93%, respectively (Table 4). The domestic prices of other crops (except wheat and rice) also fall due to the decline in input prices.

The decline in factor prices, particularly of land in the maize activity, adversely affects the earnings of the households belonging to the bottom four quintiles in the rural highlands and the bottom three quintiles in rural midland region, who engage heavily in maize production activities, leading to lower real incomes (Table 5). However, all consumers benefit from the declining maize prices raising their consumption of maize significantly,. Although wheat consumption marks a decline due to the increase in its price, there is an increase in total food consumption by all household groups including the bottom four quintiles of household groups in the rural highland region who face the declining income. Overall maize consumption increases by 1.29% and food consumption by 0.22%. The rural households in the lowland regions benefit the most in terms of their higher consumption of maize and all other food crops; increase in maize consumption is the highest for the poorest quintile rural lowland households.

Table 6 shows that the decline in domestic maize price helps reduce maize imports significantly (-5.96%). However, an increase in the domestic wheat price leads to increase in wheat imports by 1.19%. Significant fall in the domestic maize price relative to the world price increases the exports of maize by 3.39%. Table 7 presents selected economic indicators relevant to food security and economic wellbeing. Overall food availability per workforce increases by 0.30%. Technological change in maize production has a marginal positive impact on the gross domestic product of the economy, while GDP deflator and consumer price index falls by -0.11% and -0.13%, respectively.

Scenario 2: wheat productivity change

The new promising wheat varieties have much higher impact on production of wheat than in case of maize. It stimulates highest wheat production in the lowland and midland regions, 2.21% and 2.20% respectively, followed by the production in highland area, 2.11% (Table 2).

The spill-over effect of this technology change leads to increase in wheat activities. Given the relatively lower share of factor inputs and high importability, decline in demand for factors of production and their prices in wheat activities seems to have less negative influence on the rest of the activities. Though there is a contraction of rents to land and capital in wheat production, rents increase for all other sectors (Table 3). Wages increase marginally in the economy.

There is significant drop in prices faced by wheat consumers, -1.89% (Table 4). However, domestic prices increase for almost all the non-wheat food sectors. The overall effect on factor income seems to have generated higher household real income than what was observed in the case of increase in maize productivity change (Table 5). Rural highland households in the lowest quintiles experience very marginal decline in real income; all other households benefit marginally from higher real income. A decline in wheat prices increases the wheat consumption of these lower income households (Table 5). However, consumption of maize as a major staple food declines for these households due to the increase in maize prices. Overall wheat consumption in the economy increases by 0.77%. Although consumer prices do not decline for other non-wheat commodities, the positive income gain by most of the households offset the negative price effects, resulting in higher consumption by all households.

The promising wheat technology increases Kenyan wheat production, which in turn reduces imports by up to 2.8%. The decline in domestic price of wheat makes wheat more competitive to export markets, an increase of 3.28% (Table 6). Similar to Scenario 1, introduction of promising wheat varieties also increases overall long run food security in terms of raising the food availability per worker by 0.16% (Table 7). Although the overall price of the economy in terms of GDP deflator increases marginally by 0.01% and the consumer price index does not show any change, real GDP increases by 0.023%.

Scenario 3: joint technological change for maize and wheat

The combined effect of increased productivity of maize and wheat due to promising technologies brings highest increase in the production of maize and wheat. Increase in maize production is highest for the highland region, 1.33%, followed by the lowlands (1.09%) and the midlands have lowest increase, 0.70% (Table 2). On the other hand, there is higher increase in wheat production across the regions compared to the individual scenarios.

The net joint impact of increased productivities of maize and wheat on prices is dominated mainly by the change in maize technology. The rent to land in maize and wheat activities declines significantly, followed by the capital used in maize and wheat activities. It is to be noted from Table 3 that even if wages decline for all sectors in Scenario 1, the decline is moderated in Scenario 3 by increase in wages from increased wheat productivity as in Scenario 2. Increased output of these two staples leads to significant decline in their consumption prices and marginal decline in other food items (Table 4).

The significant decline in factor incomes adversely affects the real income of the lower four quintiles of rural highland households, (Table 5). However, all the households benefit from the decline in consumer prices of maize and wheat leading to overall decline in for all households. The aggregate consumption of maize, wheat and the overall food in the economy increase by 1.28%, 0.58% and 0.19%, respectively. Benefits are significant for lowland rural households, the poorest regions. All the households benefit in terms of increase in energy intake.

Imports of maize and wheat decline significantly, -5.71% and -1.67%, respectively (Table 6). At the same time, lower domestic prices of wheat and maize compared to the fixed world prices induce the future export competitiveness of both maize and wheat increasing exports by 3.40% for wheat and 3.26% for maize. The increased productivity due to promising maize and wheat varieties increases food availability per worker (0.46%), while the GDP deflator and consumer price index in the economy fall by 0.10% and 0.13%, respectively (Table 7).

Scenario 4: technological change with reduced trade and transport costs

Reduction of the transport margin for maize and wheat reduces the buying prices of final household consumption goods as well as the intermediate inputs. A combination of a reduction in transport margins and an increase in maize and wheat productivity due to promising technologies is expected to generate a higher positive impact on production of the two crops in the long run as consumers face lower prices. In order to assess the net gain of combined reduction in transport margins and increased productivities of maize and wheat over the joint productivity increase of these crops, throughout our analysis in this section in this section we contrast the impacts of Scenario 4 against the previous Scenario 3.

Maize production in highland, lowland and midland regions increases by 0.71%%, 0.62% and 0.65%, respectively over the Scenario 3 (Table 2). Highland regions experience the highest increase in wheat production (1.12%), followed by midland (0.84%) and lowland (0.49%) regions. The reduction in transport margin is expected to spur the demand for intermediate inputs because of the reduced buying prices. It is seen from Scenario 3 that the increase in maize and wheat technology reduces the demand for factor prices. With the increased margins wages and rents to land increase compared to Scenario 3 (Table 3). Consumer prices of maize and wheat even decline further than earlier scenario, -1.79% and -1.51% respectively (Table 4). The lower four quintile rural households in highlands, who suffer decline in real income in the previous scenario, experience highest increase in the real income over the previous scenario (Table 5). Overall maize and wheat consumption increases by 0.85% and 0.81%, respectively. The rural highlanders gain the most, increasing not only their consumption of maize, increasing their total food consumption as well as non-food consumption. All households benefit from both food and non-food consumption. The poorest rural households in all three regions benefit the most in terms of increasing their consumption as well as energy intake levels

With higher production activities and further decline in maize and wheat prices in Scenario 4 compared to Scenario 3 the imports of these crops also decline while export competitiveness of both crops also increases. The food availability per workforce increases by 0.32% for whole economy (Table 7). Economic growth in terms of real gross domestic product also fares better than the other scenarios, attaining an increase of 0.11%. Consumer price index marks a decline of -0.08%; although the GDP deflator increases marginally over the Scenario 3, it still declines compared to the baseline.

3. Conclusion

The potential of maize and wheat technologies in enhancing the wellbeing of the households in the long run is simulated through the introduction of promising varieties as well as lower trade and transport margins in a dynamic recursive CGE model. The model considers flows between economic sectors in three agro-ecological regions: highland, midland and lowland. We update our baseline scenario for maize and wheat by introducing the trends in exogenous productivity growth rates to 2030 based on IMPACT data. The change in productivity due to promising varieties over the existing cultivars is estimated using crop simulation model (DSSAT undertaken by CIMMYT). In addition to the technology scenarios where increases in productivity of maize and wheat are implemented, we consider a scenario that combines increased productivity with a reduction in the transport margin for the two crops.

An improved maize productivity increases maize production in all the regions, increasing overall food availability per worker by 0.30%. The economy also experiences a marginal gain in GDP growth and declining consumer price index (-0.13%). An increase in maize productivity with subsequent reduction in factor prices adversely affects the incomes of bottom four quintile household groups in rural highland region, who engage widely in maize production. Although wheat consumption of these bottom four quintiles highland households in the rural highlands declines due to the increase in wheat prices, total food consumption, including maize, increases for these households due to the decline in consumer prices of maize and other products. Rural households in the lowlands gain the most in terms consumption among all household groups.

Introduction of promising wheat varieties brings significant rise in wheat production in all regions. The economy gains in terms of increased food availability level (0.16%) and marginal GDP growth. Consumer price of wheat declines by 3.85%, triggering a significant increase in the consumption of wheat. However, overall price level remains almost unchanged. The negative impact on the real income of households in agricultural activities resulting from the introduction of new wheat varieties is relatively less than that resulting from the adoption of new maize varieties, mainly because of increase in wages and rents to land. The decline in wheat prices increases wheat consumption of all the households across regions. Though total maize and food consumption declines for most of the highland rural households due to the increase in maize prices, positive changes in real household income lead to a marginal increase in overall food consumption.

Nevertheless, introduction of promising maize and wheat varieties jointly will have a much more encouraging effect on overall output and economic growth, particularly on production of maize and wheat, which leads to a fall in the respective prices for the two staples plus other food crops. Food availability per workforce increases by 0.32%. Total food consumption including maize and wheat increases significantly, although real income of highland rural households experiences a decline.

The reduction in trade and transport margins in combination with productivity improvements for the two crops further enhances the positive impacts on households and the economy. This leads to an increase in overall food availability in the economy with decline in consumer prices more than the other scenarios. Increased production induces a significant decline in consumer prices for both staples. All the households experience gain in real income compared to other scenarios mainly due to the positive income from labour and land. This scenario enhances food consumption and hence, the poorest rural households in all three regions benefitting the most from the joint interventions. Unlike the other scenarios, the increase in real income also leads to increased non-food consumption for all the households, indicating significant income linkages with the non-farm sectors.

In short, the foresights for food security in Kenya can be enhanced through increased productivity growth for these crops. This effect can be further increased if supported by a policy which reduces the trade and transport margins. Productivity growth from promising varieties enhances food security, both in terms of food availability and consumption. The consumption and food security effects are much stronger for maize than wheat varieties. Moreover, the increased production of these staples and the consequent decline in their prices, reduces import dependency, while their respective export competitiveness increases. Despite a marginal decline in the real incomes of the poorest maize producing highland rural households in most of the scenarios, their food consumption increases. Moreover, households in the lowland region of the country experience the highest gain in food consumption. The food security and welfare effects are significantly enhanced when technological change is complemented by improvements in market access. This increases consumption of both food and non-food commodities and further reduces import dependency for the major staples.

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Table A1: Baseline maize and wheat yields, trend productivity growth and yield gain from promising varieties

Baseline scenario	Yield in the base year (ton/ha)[1]	Trend productivity rates in the baseline (%)[2]					Yield gain brought by promising variety[3]	
	2007	2008-2010	2010-2015	2015-2020	2020-2025	2025-2030	Gain (%)	Gain (kg/ha)
Maize								
Highland	2.035	3.5	3.4	2.8	2.0	2.1	5.00	89.0
Lowland	1.740	3.5	3.4	2.8	2.0	2.1	4.51	72.4
Midland	1.835	3.5	3.4	2.8	2.0	2.1	4.28	65.1
Wheat								
Highland	3.773	6.2	4.2	3.9	3.6	3.6	3.02	96.7
Lowland	1.247	6.2	4.2	3.9	3.6	3.6	2.69	57.2
Midland	2.503	6.2	4.2	3.9	3.6	3.6	2.92	30.9

1. Calculated using IMPACT and crop model data
2. Based on IMPACT studies: Trend productivity growth is driven by technological and agronomic improvements
3. For maize based on experimental data and for wheat, data from DSSAT

Table 2: Impacts on output in 2030

	% change over baseline			% change from Scenario 3
	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Maize-hghl	1.23	0.10	1.33	2.04
Maize-lowl	1.01	0.09	1.09	1.71
Maize-midl	0.61	0.09	0.70	1.35
Wheat-hghl	0.40	2.11	2.52	3.63
Wheat-lowl	0.16	2.21	2.38	2.87
Wheat-midl	0.27	2.20	2.48	3.31
Oth crops-hghl	0.03	0.02	0.05	0.13
Oth crops-lowl	-0.07	-0.01	-0.07	0.01
Oth crops-midl	-0.09	0.00	-0.09	0.00
Industries-highl	-0.46	-0.25	-0.70	-0.92
Industries-lowl	-0.47	-0.53	-1.00	-1.45
Industries-midl	0.70	0.45	1.14	1.88
Services-highl	0.02	0.02	0.04	0.02
Services-lowl	-0.03	0.01	-0.02	-0.05
Services-midl	-0.11	-0.05	-0.16	-0.27

Table 3: Impacts on factor input prices in 2030

	Scenario 1(% change over baseline)			Scenario 2 (% change over baseline)		
	Labour	Land	Capital	Labour	Land	Capital
Maize-hghl	-0.16	-11.81	-5.50	0.02	0.37	0.19
Maize-lowl	-0.05	-12.07	-6.20	0.04	0.36	0.20
Maize-midl	-0.06	-12.36	-6.14	0.04	0.36	0.20
Wheat-hghl	-0.16	1.00	0.21	0.02	-2.52	-0.74
Wheat-lowl	-0.05	0.84	0.47	0.04	-2.56	-1.52
Wheat-midl	-0.06	0.91	0.27	0.04	-2.49	-0.89
Oth crops-hghl	-0.14	-0.02	0.12	0.02	0.08	0.05
Oth crops-lowl	-0.05	-0.09	0.11	0.04	0.05	0.04
Oth crops-midl	-0.06	-0.05	0.12	0.04	0.06	0.05
Industries-highl	0.02		-0.10	0.03		0.06
Industries-lowl	0.02		-0.07	0.03		0.03
Industries-midl	0.04		-0.06	0.05		0.03
Services-highl	0.00		0.09	0.02		0.05
Services-lowl	0.00		0.01	0.03		0.05
Services-midl	0.04		0.06	0.06		0.04

Table 3 (Continued): Impacts on factor input prices in 2030

	% change over baseline)			% change from Scenario 3
	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Maize-highl	1.23	0.10	1.33	2.04
Maize-lowl	1.01	0.09	1.09	1.71
Maize-midl	0.61	0.09	0.70	1.35
Wheat-highl	0.40	2.11	2.52	3.63
Wheat-lowl	0.16	2.21	2.38	2.87
Wheat-midl	0.27	2.20	2.48	3.31
Oth crops-highl	0.03	0.02	0.05	0.13
Oth crops-lowl	-0.07	-0.01	-0.07	0.01
Oth crops-midl	-0.09	0.00	-0.09	0.00
Non-agr-highl	-0.22	-0.12	-0.33	-0.45
Non-agr-lowl	-0.25	-0.26	-0.51	-0.75
Non-agr-midl	0.29	0.20	0.49	0.80

Table 4: Impact on local and composite goods prices in 2030

	Scenario 1		Scenario 2		Scenario 3		Scenario 4	
	Local	Composite	Local	Composite	Local	Composite	Local	Composite
Maize	-4.05	-3.93	0.10	0.10	-3.96	-3.84	-5.77	-5.63
Wheat	0.45	0.31	-2.76	-1.89	-2.33	-1.59	-4.04	-3.10
Other food	-0.11	-0.10	0.01	0.01	-0.10	-0.10	-0.07	-0.08
Non-food	0.04	0.03	0.04	0.03	0.07	0.07	0.07	0.07

Note: The composite price is the weighted average of local and import prices.

Table5: Impacts on household food and non-food consumption and real income by 2030

	Scenario 1 (% change over baseline)					Scenario 2 (% change over baseline)				
	Maize	Wheat	Total food	Non-food	Real income	Maize	Wheat	Total food	Non-food	Real income
h-hghl-rur1	1.06	-0.46	0.03	-0.33	-0.39	-0.04	0.68	-0.02	0.00	-0.01
h-hghl-rur2	1.12	-0.41	0.04	-0.28	-0.32	-0.03	0.70	-0.01	0.00	0.00
h-hghl-rur3	1.20	-0.35	0.06	-0.22	-0.24	-0.03	0.71	-0.01	0.01	0.00
h-hghl-rur4	1.31	-0.27	0.10	-0.14	-0.14	-0.02	0.73	0.000	0.02	0.01
h-hghl-rur5	1.39	-0.17	0.13	-0.05	0.00	-0.01	0.73	0.01	0.02	0.02
h-hghl-urb1	1.26	0.00	0.23	0.15	0.12	0.00	0.89	0.02	0.06	0.03
h-hghl-urb2	1.14	-0.01	0.18	0.13	0.14	0.01	0.82	0.02	0.06	0.03
h-hghl-urb3	1.01	-0.06	0.14	0.07	0.11	0.00	0.74	0.02	0.05	0.03
h-hghl-urb4	1.04	-0.05	0.14	0.08	0.12	0.00	0.76	0.02	0.05	0.03
h-hghl-urb5	0.99	-0.06	0.14	0.06	0.14	0.00	0.72	0.01	0.03	0.03
h-lowl-rur1	1.93	0.04	0.45	0.20	0.07	0.01	0.91	0.03	0.06	0.04
h-lowl-rur2	1.89	0.04	0.47	0.19	0.08	0.00	0.88	0.02	0.05	0.04
h-lowl-rur3	1.86	0.02	0.37	0.16	0.07	0.00	0.88	0.02	0.04	0.04
h-lowl-rur4	1.81	0.02	0.34	0.15	0.11	0.00	0.85	0.02	0.04	0.03
h-lowl-rur5	1.74	-0.01	0.34	0.12	0.11	0.00	0.84	0.02	0.04	0.03
h-lowl-urb1	1.66	-0.07	0.19	0.07	0.08	0.02	0.85	0.04	0.07	0.04
h-lowl-urb2	1.62	-0.06	0.13	0.07	0.11	0.02	0.82	0.03	0.06	0.04
h-lowl-urb3	1.70	-0.03	0.18	0.10	0.14	0.01	0.83	0.03	0.05	0.03
h-lowl-urb4	1.66	-0.05	0.17	0.08	0.12	0.02	0.83	0.03	0.06	0.04
h-lowl-urb5	1.62	-0.07	0.14	0.06	0.14	0.00	0.81	0.02	0.04	0.03
h-midl-rur1	1.57	-0.15	0.44	-0.01	-0.13	0.00	0.82	0.02	0.05	0.03
h-midl-rur2	1.58	-0.14	0.39	0.00	-0.10	0.00	0.83	0.02	0.04	0.04
h-midl-rur3	1.13	-0.09	0.27	0.05	-0.04	0.00	0.85	0.02	0.05	0.04
h-midl-rur4	1.11	-0.06	0.25	0.07	0.03	0.00	0.82	0.02	0.05	0.04
h-midl-rur5	1.09	-0.04	0.21	0.09	0.12	0.01	0.80	0.02	0.05	0.05
h-midl-urb1	1.63	-0.05	0.25	0.07	0.12	0.01	0.81	0.03	0.05	0.04
h-midl-urb2	1.57	-0.08	0.12	0.05	0.10	0.02	0.80	0.04	0.06	0.04
h-midl-urb3	1.62	-0.07	0.12	0.06	0.12	0.02	0.83	0.04	0.06	0.04
h-midl-urb4	1.65	-0.05	0.20	0.07	0.14	0.01	0.83	0.03	0.05	0.04
h-midl-urb5	1.69	-0.03	0.27	0.09	0.16	0.01	0.84	0.03	0.05	0.05
Total	1.29	-0.19	0.18	0.01	-0.10	-0.01	0.77	0.01	0.03	0.03

Table 5(Continued): Impacts on household food and non-food consumption by2030

	Scenario 3 (% change over baseline)					Scenario 4 (% change from Scenario 3)				
	Maize	Wheat	Total food	Non-food	Real income	Maize	Wheat	Total food	Non-food	Real income
h-hghl-rur1	1.02	0.22	0.01	-0.33	-0.40	1.10	0.99	0.46	0.43	0.37
h-hghl-rur2	1.09	0.28	0.02	-0.28	-0.32	1.04	0.93	0.39	0.36	0.32
h-hghl-rur3	1.17	0.35	0.06	-0.21	-0.24	0.99	0.88	0.33	0.30	0.28
h-hghl-rur4	1.29	0.46	0.10	-0.12	-0.13	0.93	0.81	0.25	0.23	0.22
h-hghl-rur5	1.38	0.56	0.14	-0.03	0.02	0.80	0.68	0.13	0.11	0.12
h-hghl-urb1	1.26	0.88	0.25	0.21	0.15	0.59	0.72	0.06	0.08	0.05
h-hghl-urb2	1.15	0.81	0.20	0.19	0.17	0.53	0.65	0.03	0.05	0.03
h-hghl-urb3	1.01	0.69	0.16	0.12	0.14	0.49	0.61	0.04	0.06	0.06
h-hghl-urb4	1.04	0.71	0.16	0.12	0.15	0.50	0.62	0.03	0.05	0.05
h-hghl-urb5	0.99	0.67	0.16	0.10	0.17	0.45	0.56	0.02	0.02	0.03
h-lowl-rur1	1.94	0.95	0.48	0.26	0.11	1.07	0.93	0.28	0.24	0.17
h-lowl-rur2	1.90	0.93	0.49	0.24	0.11	1.02	0.88	0.26	0.21	0.15
h-lowl-rur3	1.86	0.90	0.39	0.21	0.11	0.99	0.86	0.21	0.19	0.15
h-lowl-rur4	1.81	0.87	0.36	0.20	0.15	0.90	0.77	0.14	0.12	0.09
h-lowl-rur5	1.75	0.83	0.36	0.16	0.14	0.89	0.75	0.16	0.12	0.10
h-lowl-urb1	1.69	0.78	0.23	0.14	0.13	0.95	0.82	0.17	0.19	0.17
h-lowl-urb2	1.64	0.76	0.16	0.13	0.15	0.85	0.72	0.08	0.11	0.11
h-lowl-urb3	1.71	0.80	0.21	0.16	0.17	0.81	0.68	0.04	0.06	0.05
h-lowl-urb4	1.68	0.78	0.20	0.14	0.15	0.84	0.71	0.08	0.10	0.09
h-lowl-urb5	1.62	0.74	0.16	0.10	0.17	0.80	0.67	0.04	0.07	0.07
h-midl-rur1	1.57	0.67	0.46	0.04	-0.09	1.07	0.94	0.43	0.31	0.23
h-midl-rur2	1.58	0.68	0.41	0.04	-0.07	1.05	0.92	0.38	0.28	0.22
h-midl-rur3	1.14	0.75	0.29	0.10	0.00	0.70	0.90	0.24	0.27	0.20
h-midl-rur4	1.11	0.75	0.27	0.12	0.07	0.63	0.81	0.18	0.20	0.16
h-midl-rur5	1.10	0.76	0.23	0.14	0.17	0.56	0.70	0.10	0.11	0.11
h-midl-urb1	1.65	0.76	0.28	0.12	0.16	0.82	0.69	0.10	0.08	0.09
h-midl-urb2	1.59	0.72	0.15	0.11	0.14	0.81	0.68	0.06	0.09	0.09
h-midl-urb3	1.64	0.75	0.16	0.12	0.17	0.83	0.70	0.05	0.09	0.09
h-midl-urb4	1.66	0.77	0.24	0.13	0.18	0.82	0.69	0.08	0.08	0.08
h-midl-urb5	1.71	0.80	0.31	0.14	0.21	0.83	0.69	0.09	0.07	0.07
Total	1.28	0.58	0.19	0.04	-0.07	0.85	0.81	0.19	0.12	0.25

Table 6: Impacts on exports and imports in 2030

	Scenario 1 (% change over baseline)		Scenario 2 (% change over baseline)		Scenario 3 (% change over baseline)		Scenario 4 (% change from Scenario 3)	
	Export demand	Imports	Export demand	Imports	Export demand	Imports	Export demand	Imports
Maize	3.39	-5.96	0.01	0.27	3.40	-5.71	3.675	-6.523
Wheat	-0.02	1.19	3.28	-2.81	3.26	-1.67	3.168	-1.809
Other Food	0.08	-0.17	0.01	0.05	0.09	-0.12	0.16	0.06
Non-food	-0.04	0.06	-0.02	0.07	-0.05	0.11	-0.02	0.16

Table 7: Indicators of economic well-being in 2030

	Scenario 1 (% change over baseline)	Scenario 2 (% change over baseline)	Scenario 3 (% change over baseline)	Scenario 4 (% change over Scenario 3)
Food availability per workforce (All Kenya)[a]	0.301	0.157	0.458	0.316
Real GDP	0.034	0.023	0.058	0.113
GDP deflator	-0.107	0.010	-0.097	0.022
CPI	-0.131	0.000	-0.131	-0.077
Unemployment rate	0.07	-0.03	0.04	-0.022

[a] Food availability is the net supply (production plus imports net of exports) of food crops and livestock in the economy

Appendix-I

Table A1: Structure of the Kenya Economy

	National	Highland	Lowland	Midland
Population (millions)	37.75	16.70	4.73	16.32
GDP per capita (KSH million)	42469	55612	18133	36074
Share of national GDP (%)		58	5	37
Share of regional GDP (%)				
Agriculture		69.6	5.5	24.9
Maize		78.7	0.9	20.4
Wheat		80.1	2.0	17.9
Other crops		83.4	0.5	16.0
Livestock		24.7	22.5	52.8
Non-agriculture		54.2	5.3	40.5
food processing		64.3	3.8	31.9
Share of cultivated land (%)		82	1	17
Share of regional cultivated land (%)				
Maize		78.7	0.9	20.4
Wheat		80.1	2.0	17.9
Other food crops		81.9	0.7	17.4
Share of Maize and wheat in consumption basket (%)				
Total food (incl. livestock & processed food)				
Rural households		56.6	76.0	57.8
Urban households		35.9	51.6	41.4
Maize				
Rural households		4.2	4.8	5.4
Urban households		1.1	0.6	1.3
Wheat				
Rural households		0.1	0.1	0.1
Urban households		0.0	0.0	0.0
Livestock				
Rural households		8.3	29.0	11.3
Urban households		7.4	8.1	6.2
Processed food				
Rural households		21.2	25.3	22.1
Urban households		16.3	28.5	21.2
Distribution of Income (% of national income)	100	67.38	4.29	28.32
Labour	100	54.39	6.55	39.06
Land	100	82.21	0.68	17.11
Livestock	100	26.06	21.98	51.96
Capital	100	77.52	2.29	20.18

Table A3: Structural components of supply and demands of the economy

	% of total supply			% of total supply				
	Imports	Production	Total	Exports	Intermediate demand	Household consumption	Investment	Total
Maize	4.25	95.75	100	0.18	51.71	48.11		100
Wheat	34.43	65.57	100	1.23	95.48	3.29		100
Oth food	14.54	85.46	100	4.30	15.37	80.33		100
Non-food	13.60	86.40	100	28.11	44.36	21.64	5.89	100