working paper
2016-17

Economy-wide impacts of technological change in food staples in Ethiopia: A macro-micro approach

Lulit Mitik Beyene
Bekele Shiferaw
Amarendra Sahoo
Sika Gbegbelegbe

August 2016

pep
partnership for economic policy

Economy-wide impacts of technological change in food staples in Ethiopia: A macro-micro approach

Abstract

This paper assesses the potential impacts from the introduction of high yielding and drought tolerant varieties of major food staples (wheat and maize) in Ethiopia. We develop a dynamic Computable General Equilibrium model with a micro-simulation module to examine the growth, poverty and distributional impacts of agricultural innovations. The analysis shows that introduction of improved varieties of these food staples is likely to boost the cereal sector in the country. Other agricultural sub-sectors grow due to increased labour supply. Given that these staple cereals represent an important share of food consumption for Ethiopian households, the poverty impact of the interventions is positive. Although rural households benefit from higher gains in real consumption, poverty declines more in urban areas compared to the rural. This is mainly because the rural poor are generally far from the poverty line with a higher initial poverty gap compared to urban households and the urban poor benefit from price effects. As productivity-enhancing technologies are introduced, there is a need for policy interventions in rural areas targeting non-agricultural sectors to enhance growth linkages, increase employment and stimulate inclusive growth.

Authors

Lulit Mitik Beyene
Director
Institute for Economic and Social Development Research
Addis Ababa, Ethiopia

Bekele Shiferaw
Partnership for Economic Policy
Nairobi, Kenya

Amarendra Sahoo
Research Fellow
Partnership for Economic Policy
Nairobi, Kenya

Sika Gbegbelegbe
Research Fellow
Partnership for Economic Policy
Nairobi, Kenya

Acknowledgement

This research was carried out with support from the International Maize and Wheat Improvement Center (CIMMYT) and the Partnership for Economic Policy (PEP). PEP receives funding from the Department for International Development (DFID) of the United Kingdom (or UK Aid) and the Government of Canada through the International Development Research Center (IDRC). The Authors are also grateful to anonymous reviewers for useful comments. The usual disclaimers apply.

Table of contents

I. Introduction

Agriculture has continued to retain its importance in Ethiopia's economic growth contributing about 42% of GDP, with 80% of employment and 70% of export earnings in 2014 (African Economic Outlook, 2015). With almost 85% of its population living in rural areas and depending on agriculture for its livelihoods, agriculture has assumed a steering role in enhancing economic growth and importantly in reducing poverty and food insecurity in the country. The share of population living below poverty line in Ethiopia has declined from 45.5% in 1995/96 to 29.6% in 2010/11, rural households having much higher poverty than their urban counterparts (CSA, 2011). Despite the decline in poverty and increase in total agricultural production, existing evidence shows that almost 40% of the households are still food deficient using the threshold of 2550 kilocalories per adult equivalent per day (CSA, 2014). However, the dominance of agriculture has also declined over the years; its contribution to GDP declined from 52% in 2009 to about 42% in 2014.

The vast majority of Ethiopian farmers are small-scale producers – estimates show about 94% of Ethiopian farmers rely on less than 5 hectares of land, of which 55% cultivate less than 2 hectares. Crop productivity still remains very low relative to its potential yields, only averaging 2.21 t/ha between 2010 and 2014 (World Bank, 2014). Moreover, only 5% of the country's agricultural land is irrigated, largely leaving agriculture to the fate of unreliable and poorly distributed rains. According to CSA (2014a), low productivity could be attributed to many factors including land degradation, small farm size, recurrent drought and poor farm technology. High food prices since 2008 also affected food security for the poor and net-buying households. Whereas much of the recent production growth is often attributed to area expansion, there is significant potential for increasing productivity of food crops in Ethiopia through the introduction of promising crop technologies.

It is recognized that nationally, teff, maize and wheat, in particular, are at the center of the increasingly vibrant agricultural output markets in Ethiopia (Minten et al., 2012). Benson et al. (2014) found that a combined increase in the production of these staples would bring invariably higher consumption and reduced poverty across households in Ethiopia. The significance of maize and wheat in production and consumption, particularly in terms of their high share in calorie intake, has stimulated a national interest for these crops in terms of technology development and dissemination. Maize contributes about 29% of the calorie intake from total cereal consumption, followed by wheat and teff contributing about 21% and 17%, respectively (FAO, 2013; Berhane et al., 2011). Expansion in the production of these staples stimulated through technological change is expected to support higher calorie intake and improve household and national food security.

Maize is the second most widely cultivated crop after teff in Ethiopia with around 28% share in total cereal production and grown mostly under rainfed conditions. Maize consumption as food constitutes about 20% in total cereal consumption in 2013 and has grown by 13% in 2013 compared to 2009 (FAO, 2013). However, the share of maize consumption from the total production declined from 89% in 2009 to about 78% in 2013, while the share of maize as feed has grown from 5% to 13% between these years. This indicates the changing food habits of households towards poultry and other livestock products due to growing urbanization and income changes. The maize yield in Ethiopia increased from 2.19 t/ha in 2009 to 3.25 t/ha (about 47% increase) in 2013, while harvested area expansion was only 17% over between this periods (FAO, 2013). Though Ethiopia compares favourably with the main maize producing countries in Sub Saharan Africa, the country is yet to achieve its potential in terms of maize production because of the old varieties still dominating the seed system in the country and inadequate quantity and quality of foundation seed for the major food staples (Abate et al., 2015). According to Zeng et al. (2015) the treatment effect estimates at the plot level suggest a yield advantage of 47.6-63.3% for improved maize varieties over traditional varieties with some cost increase due to additional inputs; however, the limited adoption of improved maize varieties has led to poverty reduction by 0.08-1.3%.

Wheat has assumed its importance as an important staple in Ethiopia and accounts for about 15% of the total cereal production and 20% of the cereal consumption. Ethiopia is still deficient in terms of wheat production to meet the national requirements. In 2009, the country had about 10% wheat production deficit, which led to its imports of about 40% of its total supply (FAO, 2013). Ethiopia is the only country in sub-Saharan Africa where smallholder wheat production meets more than 70% of the national consumption demand (Shiferaw et al., 2011). However, despite the periodic variability, wheat production in 2013 has gone up by 60% over 2009 and imports of wheat have declined by 53% (FAO, 2013). About 72% of the wheat production is used for domestic food consumption. The improvements in wheat production in Ethiopia are primarily due to development and dissemination of improved wheat varieties by the International Maize and Wheat Improvement Center (CIMMYT) in collaboration with Ethiopian Institute of Agricultural Research (EIAR). Thanks to the significant efforts, only about 30% of the wheat growers are not currently benefiting from modern varieties (Shiferaw et al., 2014). Wheat yield in Ethiopia which was 1.83 ton/ha in 2009 and has increased by around 30% to 2.4 ton/ha in 2013 (FAO, 2013). However, the primarily rainfed wheat yields for smallholder farmers in Ethiopia are still low and lagging behind by about 33% and 60% below Kenyan and South African averages (between 2009 and 2013).

Meeting the current and fast growing future demand for food strapless in Ethiopia will require better crop-breeding, better crop resistance to diseases, pest, resilience and adaption to climate shocks and reduced use of external inputs (Shiferaw et al., 2011a, Shiferaw et al., 2013). Though the performance of maize and wheat in Ethiopian agriculture has been commendable in recent years, it is understood that there is enormous potential for further productivity growth in these crops, which is important to meet the growing demand and food deficits in the country. The major challenges to productivity growth are related to biotic and abiotic constraints that still hinder smallholder production. Widely adopted disease resistant and drought tolerant cultivars are very important to achieve these objectives. Introduction of high yield and stress tolerant varieties is expected to improve household food security as well as generate economy-wide impacts which will contribute future economic growth, food consumption and poverty reduction. This study therefore aims to assess the long run economy-wide impacts of promising future maize and wheat varieties compared to the existing varieties of these crops with the help of a dynamic sequential computable equilibrium (CGE) model.

Some of the earlier economy-wide studies have also emphasized the importance of growth agriculture and staple crops in the Ethiopian economy. The CGE model results by Diao and Pratt (2007) found that within agriculture, cereals and other staple crops played a greater role in reducing poverty and increasing growth than other sectors in Ethiopia. An economy-wide study by Dorosh and Thurlow (2009) indicated that Ethiopia should sustain its growth potential by meeting its targets for crop yields and yield improvements, especially in cereals which are more effective in improving rural income and poverty. Similarly, Mitik and Engida (2013) showed the significance of agriculture-led investments in improving poverty and food security, while Benson et al. (2014) emphasized the potential of productivity interventions in staple cereals in bringing higher growth and reducing extreme poverty in Ethiopia. Like many of these studies, our analysis uses macro modeling and micro-simulations for household poverty analysis. Our study however benefits from data which uses systematic crop growth modeling tools to estimate the productivity improvement from two important staples (maize and wheat) based on prior analysis conducted for promising drought-tolerant and high-yielding maize and wheat varieties being developed for Ethiopian farming systems. This is used to assess the potential impact of these carefully simulated productivity improvements due to higher yields from maize and wheat cultivars relative to the existing varieties of these important food staples in Ethiopia. The model also assumes that investments in research and development on these promising technologies have already been made prior to the adoption year. The macro CGE analysis is followed by a micro simulation approach to determine the poverty and distributional impacts of the new technologies.

The rest of the paper develops as follows. The next section briefly presents reflections on the agriculture and food security situation in Ethiopia. The CGE model along with the micro simulation approach for poverty analysis and scenarios are presented in the third section. Results are discussed in the fourth section, while the last section concludes the paper.

II. Agriculture and food security in Ethiopia

Food security has been a big challenge in Ethiopia since 1970s. Series of rain failures and consequent loss of livestock contributed to the severity of famine in 1983-1985. The famine vulnerability continued through the mid-1990s owing to regional conflicts and protracted droughts in many parts of the country (Webb et al., 1992; von Braun and Olofinbiyi, 2007). Ethiopia faced another famine in 2002 despite good harvest. There was a sharp fall in food prices below the historic average, where maize prices in surplus regions fell by almost 80% creating disincentive for input use by producers (von Braun and Olofinbiyi, 2007). As a consequence, Ethiopia became one of the largest recipients of international food aid in Sub-Saharan Africa. Although the country has managed to ward off widespread famine since 1991, localized food shortages continue to be a recurrent phenomenon (Graham et al., 2012). The country has demonstrated prevalence of under-nourishment among large portion of the population. The World Bank (Prevalence of Undernourishment index 2011-2015) estimates that as of 2013 as high as 35% of Ethiopian population is still undernourished. The economy loses around 16.5% of its GDP each year to the long-term effects of child malnutrition (COHA, 2013). Despite the reduction in poverty ratio in recent years from 38.7% in 2005 to 29.6% in 2011, poverty severity (higher weight on households/individuals, who are further below the poverty line) has worsened, i.e. it has increased from 2.7% to 3.1%, during the same period (World Bank Group, 2015).

In order to alleviate poverty through accelerated investment in agriculture and sustained economic growth, the Government of Ethiopia adopted the Agriculture Development Led Industrialization (ADLI) strategy since 1993. The main objective of this strategy is to increase the productivity of smallholder farmers through the use of new technologies and the dissemination of information on the agricultural practices in order to generate savings and increase domestic demand for the non-agricultural sectors (Dercon and Zeitlin, 2009; Diao, 2010). As a part of the economic development and structural transformation programmes under the of ADLI plan, several policy programmes were formulated, e.g. Poverty Reduction Strategy Program (PRSP), Plan for Accelerated and Sustainable Development to End Poverty (PASDEP), Growth and Transformation Plan (GTP), Agricultural Sector Policy and Investment Framework (PIF) and many other to align with the

Comprehensive Africa Agriculture Development Programme (CAADP). World Bank Group (2015) has observed that agricultural output growth in Ethiopia has had a strong causal impact on poverty reduction; agricultural growth has caused almost 4% annual reductions in poverty during the post 2005 period.

Although agriculture has recorded significant growth in recent years, recurrent droughts and high variability in production continued to compound the historic stagnation in productivity in Ethiopian agriculture (Byerlee et al., 2007). The economy has faced extreme variability in agricultural performance as well as economic growth till 2004; although agricultural growth has remained positive since 2004, fluctuations are still noticeable (Figure 1). The graph also explains the dominance of agriculture in influencing the fluctuation in national GDP; however, the growth rate of agriculture has been lower than that of GDP in recent years. Most of the agricultural production in Ethiopia is rainfed and subject to weather fluctuation. Robinson et al. (2013) have observed that variance in crop yields in Ethiopia has increased over time and climate change shocks have become more intense by increasing variability in agriculture income. However, studies have suggested that fertilizer, improved seeds and production practices have the potential to increase the agricultural growth in Ethiopia (Dercon and Hill, 2009; Vandercateelen, 2013) and these may reduce poverty further.

Cereal production occupies the major share of agricultural production in Ethiopia, of which teff, maize, wheat and sorghum are most important cereals in terms of area cultivate, yield and consumption. Teff constitutes almost 24% of total grain production, followed by maize (17%), sorghum (15%) and wheat (14%) (CSA, 2014b). Most of the crop production takes place in highlands where 44% of total area is cultivated, where 95% of land under crop is located, where 90% of the total population lives, and where declining vegetative cover is very common (Ayenew, 2015). Most smallholder farmers are located in the moisture-reliable cereal based highlands accounting for 59% of all farm area; on the other hand, the farm area in the drought-prone highlands represents 27% of the total area cultivated (Taffesse et al., 2011). The main season (Meher season) accounts for almost over 92% of area cultivated and 97% of total crop production. High population concentration and the consequent pressure on the moisture-prone land in the highlands, poverty of soils, along with vagaries of rainfall could lead to the frequent regional droughts in Ethiopia.

The economy has been facing fluctuations in the crop production over the years, so also the imports of food crops to bridge the deficits and meet the growing demand in the economy (Figure 2). The historical data shows that consumption demand for food crops has consistently been more than domestic production between 2004 and 2008 (Figure 2 and FAO, 2013). There were wide fluctuations in crop production till 2008 through 1990s. The production of food crops has started showing an increasing trend since 2008 mainly due to growing adoption of modern inputs and improved seeds; however, this increase is also marked by major fluctuations caused by variability of rains during the production season. Ethiopia has been facing rising overall inflation (consumer price index) as well as increasing food prices (Figure 3). The food price index consistently remains higher than the general price index and it has shown a sharp rise since 2010. Rising food prices could have hit the real income of consumers in both rural and urban areas, affecting food security, particularly for poor and vulnerable households.

Realizing the growing importance of maize and wheat in the country's crop production and food security, significant research effort has gone into developing new varieties of these crops that can enhance the food situation in the country. The collaborative research efforts of EIAR and CIMMYT have resulted in the development of widely adapted hybrid, open-pollinated, low-moisture stress and nutritionally enhanced varieties of maize between 2007 and 2013. CIMMYT has also offered significant germplasm and knowledge-base to develop high yielding and stress-tolerant (especially rust resistant) wheat varieties. Studies have observed that wheat and maize areas covered by the improved varieties in Ethiopia are about 70% and 40%, respectively (Shiferaw et al., 2014 and 2015). However, this high adoption of improved seeds mostly includes long-term seed recycling, i.e. replanting of improved seeds from own production by smallholders, (Shiferaw 2014; Spielman et al., 2012).

III. Modeling framework

3.1. The CGE Model

We build a Computable General Equilibrium model to analyze the potential impact from the introduction of promising and new improved technologies for staple crops, i.e., wheat and maize production in Ethiopia. The CGE model that we implement is based on neoclassical-structuralist general equilibrium theory. The proposed CGE model uses an adapted version of the PEP 1-t model by Decaluwé *et al.* (2013).[1] The model captures economy wide impacts on production, consumption, factor markets and prices in an economy in which producers adopt a cost minimization[2] approach and consumers a welfare maximizing behavior. We adapt the standard PEP model in its dynamic version to the Ethiopian context in order to measure the growth and welfare impacts resulting from introduction of improved technologies in the staples sector.

Economic shocks or economic policy reforms can have dynamic impacts on the economy. PEP 1-t is a sequential dynamic CGE model, also called a recursive model. For example, some reforms could be implemented gradually and therefore, their effects would be spread over successive periods. In this particular case, the dynamic model allows us to introduce productivity gains from the adoption of the new technology in 2015/16. Dynamic assignments constitute the link from one period to the next and fall into two categories: one set of statements update variables that grow at a constant rate per period; the other equations control the accumulation of capital. For the former, there is a population index, growing each period at a rate of 2.6%[3]. This index is used in the model to update the values of variables and parameters that are assumed to grow at that rate. These include: labour supply, the current account balance; minimum consumption of commodities in the LES demand equations; government current expenditures; public investment by category and by public sector industry; and, finally, changes in inventories. All categories of capital (including land) are sector specific. We assume that land is only utilized in agricultural production. Agricultural labor is only employed in agricultural production and mobile across

[1] A full description of the model can be found in Decaluwé *et al*. (2013).

[2] Producers have a cost minimization behavior in view of maximizing profit.

[3] This is based on the demographic growth rate in Ethiopia.

agricultural sub-sectors. Non-agricultural labor is mobile across all sectors except the public sector where we assume employment to be sector specific.

The CGE model is calibrated to a social accounting matrix (SAM) of Ethiopia, which was built by the Ethiopian Development Research Institute (EDRI) based on 2005-2006 data. The SAM required aggregation and disaggregation work to fit the needs and modeling requirements of the present study. In addition, the SAM has been updated to 2010-2011 to reflect, to the extent possible, the macroeconomic situation during that period and in particular the GDP shares of maize and wheat sectors. The value of the GDP for 2010-2011 at constant market price was used as a reference. Information was taken from the National Bank of Ethiopia (NBE) and the Ministry of Finance and Economic Development (MOFED) data. Our CGE model is calibrated to a SAM with 19 production activities of which 14 are agricultural sectors including wheat and maize. These activities produce 25 commodities (20 agricultural, 3 manufacturing, and 2 services). There are five primary factors of production (agricultural labor, non-agricultural labor, land, livestock, and non-agricultural capital). Non-agricultural labor is also disaggregated by occupational category (administrative and professional, unskilled, and skilled). There are six aggregate household groups: rural, small urban and big urban each disaggregated into low-income and high-income categories. The SAM has 3 tax accounts (direct and indirect taxes and import duties) as well as aggregate accounts for trade margins, government, investment and stock variation, and the rest of the world.

3.2. Poverty analysis within the CGE framework

The study uses the IFPRI extended standard recursive dynamic CGE modeling system, version 2.00 (Lofgren *et al.*, 2003), for its poverty analysis. This system endogenously estimates the impact of productivity growth on poverty by using a "top-down" approach where changes in the CGE model are imported into the micro simulation model. This uses micro data from the 2009-2010 Household income and consumption expenditure survey (HICES) for detailed information on household expenditure. Households are distinguished by income (lower and higher income) and by location (rural, semi urban and urban) in the

CGE model. Income and expenditure patterns vary considerably across these household groups.

In the micro simulation, each of the 27,835 households included in the survey are linked to the corresponding representative household in the CGE model. A second level of mapping links the commodities in the CGE model and in survey with those used in the calculation of the poverty line. Only the latter are considered in the poverty impact analysis. Changes in the real consumption of representative households in the CGE model are then passed down to their corresponding households in the survey. In the next step, real total consumption expenditures are recalculated in the survey. Household size[4] is used to calculate per capita consumption expenditure. Similar to the representative households in the CGE model, the households in the survey are heterogeneous in their consumption patterns. The micro-simulation model calculates the share of each commodity in total expenditure for each of the survey households. These weights are maintained when post-shock consumption expenditure is calculated. This new level of per capita expenditure is compared to the exogenously given poverty line, and the standard poverty measures are recalculated. The Foster Greer and Thorbecke (FGT) poverty measures are applied (Foster, Greer and Thorbecke, 1984). The 3781 Birr per year and per adult poverty line used in this study is the official poverty line (MOFED 2013). In the poverty analysis, consumption is used as the metric to measure poverty.

IV. Scenarios: Promising maize and wheat cultivars in Ethiopia

Maize is a crop which was heavily promoted by the National Agricultural Research System (NARS) in Ethiopia following the major drought of 1984 (Abate et al., 2015). Today, the crop is second to teff in terms of area but first in terms of productivity (yield) among all

[4] The population size represented by each of the survey households is updated each period using the population growth index.

cereals in the country (Abate et al., 2013). Maize has also become the most important staple food in rural Ethiopia (Abate et al., 2015).

Since the 1990s, maize production has been on a rising trend in Ethiopia. Before 2003, the growth was primarily driven by area expansion and to a smaller extent by productivity increases. However, since 2003, the reverse trend has been observed: production growth has been primarily driven by productivity growth; area expansion contributed to a smaller extent (Abate et al., 2013).

The increase in productivity growth from 2003 can be partially explained by the accelerated release of improved maize varieties since 2003. Most of the releases came from the NARS and mainly involved national research institutes working in collaboration with higher learning institutes. The Drought-Tolerant Maize for Africa (DTMA) project, led by CIMMYT and IITA, has worked with the NARS in Ethiopia to further spur the release and commercialization of drought-tolerant maize varieties. Between 2007 and 2013, seven drought-tolerant maize varieties with resistance to various diseases were released in Ethiopia under the DTMA project. These varieties have a yield advantage of 20 to 30% over checks in controlled field trials (Abate et al., 2013).

Given the substantial yield gap between farmers' fields in Africa and achievable yields, which in Ethiopia would be partially caused by poor infrastructure and lack of access to affordable fertilizer, we use estimates from Lobell et al. (2009) to adjust the yield gain brought by drought-tolerant maize varieties on farmers' fields. Lobell et al. (2009) estimate farmers' yields to be 36% of potential maize yield in mid-altitude regions of Sub-Saharan Africa. Most of the maize grown in Ethiopia is in highland or mid-altitude zones. Hence, using the conservative estimate of a 20% yield advantage of drought-tolerant maize in controlled field trials, drought-tolerant maize would bring about a yield increase of 7.1% on farmers' fields in Ethiopia (Table A1).

Wheat is another staple crop in Ethiopia whose share in cereal acreage has remained constant since the 1980s unlike that of maize which has increased substantially over time (Abate et al., 2015). However, the country has had to increasingly rely on imports to meet its wheat consumption requirements. Since 2000, the volume of imported wheat in Ethiopia has been rising at an annual compound rate of 2.57%[5]. By contrast, the value of wheat imports into the country rose by 11.09%[6] over the same period, highlighting the role that global food price shocks, partly caused by climate change, play in deepening import dependence.

In such context, high-yielding improved wheat technologies with resistance to various biophysical stresses could increase production and import substitution, thus, spurring growth in the economy. CIMMYT and its partners have been involved in developing promising wheat technologies adapted to the agro-ecologies of Ethiopia. Recent releases of improved wheat technologies consist of high-yielding varieties with resistance to stripe rust, a disease which became endemic in 2010 and caused huge losses to Ethiopian farmers (IISD, 2011; ICARDA, 2013). This study assesses wheat varieties with resistance abiotic stresses as crop models do not yet incorporate biotic stresses. Two types of promising wheat technologies are assessed: heat-tolerant wheat and drought-tolerant wheat. Clearly, heat stress does not affect wheat in the country, as the results suggest that heat-tolerant wheat varieties would not substantially increase yields across Ethiopia. However, even though wheat is grown in high rainfall areas in Ethiopia, there's a potential for wheat yields to grow by about 4% with the adoption of drought-tolerant wheat (Table A1).

Three scenarios are run to analyze the impact of improved technology in wheat and maize production in Ethiopia. The scenarios are run starting from 2015/16 which corresponds to the 6th period in the model. The first scenario simulates an increase in total factor productivity (TFP) in wheat production by 3.95%. The second scenario simulates TFP increases in maize production by 7.1%. The third scenario combines the first two. For this analysis, we assume that the new varieties are fully adopted during the first year of introduction. This means that the change in yield brought by the promising technologies will allow wheat and maize yields to be systematically 3.95% and 7.1% higher than in the reference scenario for the years following their full adoption. The model is run for five periods after the introduction of yield shock. This corresponds to the year 2019/20. These yield gains are added to the reference scenario where agricultural productivity increases in each period based on performances of the agricultural sector between 2009/10 and

[5] Computations by authors using data on maize imports from FAOSTAT.
[6] Computations by authors using data on maize imports from FAOSTAT.

2014/15. The latter are extracted from annual agricultural sample surveys conducted by the Central Statistical Authority (CSA) in Ethiopia. In addition to this, yield gains due to maintenance and research are added.

V. Results

5.1. Impact of yield gains in wheat and maize production on economic growth

The introduction of improved and promising new seed technologies is estimated to increase yield by 3.95% in wheat production and by 7.1% in maize production. After five years of implementation, the new technology increases wheat output by 2.7% and that of maize by 6.1% compared to the output levels in the reference scenario. Given the excess supply, wheat and maize are sold on the national market at a lower price (-3.2% and -6.6% respectively). This benefits households consuming maize and wheat as well as sectors using the cereals as intermediate inputs. .

As the two cereal sectors become more productive, producers reduce their labour demand (-1.4% in wheat and -1.1% in maize sectors) putting a slight downward pressure on agricultural wages (-0.2% and -0.3% respectively). This induces migration of those initially employed in the wheat and maize sectors towards other agricultural subsectors allowing a slight increase in the output of those sectors absorbing the excess agricultural labour. In aggregate, agricultural production is 0.3% and 1.0% higher in the wheat and maize scenarios compared to the reference scenario in 2019/20. The price of agricultural goods also declines, albeit marginally. The agricultural producer price index declines by 0.6% and 0.4% and the consumer price index falls by 0.4% and 0.9% in the first two scenarios. This price effects are likely to benefit the agro-processing industry and urban and rural households – especially the net buyers.

The GDP impact is small but positive (Table 1). The real GDP increases by 0.1% pulled by agricultural growth (0.2%) and the slight expansion in services sector (0.003%) in the wheat scenario. In the maize scenario, real GDP increases by 0.4% due to agricultural growth (0.8%) and the slight expansion in services sector (0.01%). Industrial GDP contracts slightly (-0.02%) in both scenarios. The changes in real GDP for industrial and services sectors are essentially induced by non-agricultural labour movement away from agriculture and industry towards services sectors.

When the new varieties of wheat and maize are introduced simultaneously, as expected, we find that the cumulative impact is higher than when we simulate the introduction of improved varieties in wheat and maize production separately. The joint introduction of new varieties of wheat and maize results in a 0.5% increase in economic growth compared to the baseline reference scenario in 2019/20 (Table 1). Agricultural GDP increases by 1% while the services sector growth remains at 0.01% higher than in the reference scenario. Industrial GDP declines slightly (-0.04%) compared to the reference scenario which is similar to the scenarios where the new varieties are introduced separately.

The three simulations show that despite the expansion in the agricultural sector, the scope of the gains by itself is not sufficient to induce growth in the industrial sector. Although the agro- industry sector is linked with the agricultural sector through production[7] and consumption linkages, the GDP gains induced by the introduction of new varieties of staple crops (wheat and maize) are not of sufficient magnitude to induce significant growth in the agro-industry. Furthermore, the fact that some agricultural sectors (such as livestock and livestock products) producing and supplying substitutes to products from the agro-industry, at more competitive prices, have grown owing to spillover effects of the expansion of the wheat and maize sectors, both through labor movements and more competitive intermediate inputs.

5.2. Income effects of yield gains in wheat and maize production

The income effect of the introduction of yield-augmenting and drought tolerant varieties in wheat and maize production is captured through the impact on labor and capital income as well as income from transfers[8]. Table 2 presents the key simulation results. While

[7] The agro industry sector uses agricultural intermediate inputs representing 46% of the sectors total intermediate consumption.

[8] Transfer income is fixed in nominal terms but indexed to the consumer price index.

nominal income declines slightly for rural households and in particular the rural low-income households, it increases moderately for the urban households. For rural households, labor income is reduced due to lower agricultural wages while capital income declines as it is affected by a declining return to agricultural land. Agricultural labor income is an important source of income for the rural low income households representing 71% of total income while it is relatively less important for the rural high-income ones as it accounts for 41% of total income. Urban households see their income slightly increase with higher returns to non-agricultural labor and capital, in which they are highly endowed.

The combined impact of the price and income effects benefits both rural and urban households. Real income, thus real consumption increases for all categories of households. As presented in the Table 3, consumption of agricultural goods increases for all households. This is due to the fact that agricultural prices have declined more than industrial ones while prices of services have slightly increased. Furthermore, rural households allocate more than half of their consumption expenditure to agricultural goods and therefore benefit relatively more than other categories of households from lower prices of agricultural products.

In the wheat only scenario, at the disaggregated level, urban households tend to benefit relatively more than the rural households; the former gain from positive income and price effects. As regards rural households, they are able to increase their consumption because the negative income effect is counteracted by falling consumer prices. Given that rural households spend a higher share of their consumption budget on agricultural products, they are able to increase their consumption at a level only slightly lower than that of urban households. Finally, while urban households tend to benefit more than the rural households, the low-income urban households benefit relatively more than the urban higher-income. In contrast, the rural low-income households benefit relatively less than the rural high-income households.

In the maize only scenario, consumption of agricultural goods increases for all households in particular for the rural low-income households. Although urban households see their real consumption increase relatively less than the rural, the urban low-income households benefit relatively more than the urban higher-income households. The urban low-income, in particular those in small urban settings, tend to benefit relatively more than other urban households.

The income effect for households is amplified when the new wheat and maize technologies are introduced simultaneously (Table 4). Rural households and more particularly the rural low-income households have a declining nominal income while urban households benefit from a slight increase in income with the same scope for all categories.

Due to falling prices, the impact on real income (thus consumption) is positive for all categories of households (Table 5). The rural low-income households have the highest consumption gains followed by the rural higher-income and the low-income households in small urban areas. Overall, low-income households in both rural and urban areas tend to increase their consumption relatively more than those with higher income. This is because rural households and in particular the low-income rural households allocate at least half of their consumption expenditure to staple food crops for which maize and wheat remain major consumption items and prices have declined. Similarly, the low-income urban households allocate a higher share of their consumption budget to buy agricultural products (especially cheaper calorie sources like maize and wheat) compared to higher-income households in small and big urban areas who tend to higher income elasticities or allocate a higher share to other food items (e.g. teff and animal foods – meat and dairy products) (Tafere et al., 2010).

5.3. Impact of yield gains in wheat and maize production on poverty

The micro-simulation model captures the potential impacts from the introduction of the wheat and maize technologies on poverty. We find that the introduction of high yielding and drought tolerant varieties of wheat and maize is likely to contribute to inclusive growth and poverty reduction at national level. Table 6 presents the effect on poverty incidence, depth and severity.

The poverty incidence declines at national level. On a cumulative basis, poverty is reduced by 1.1% after five years of implementation of wheat technology. The introduction of new varieties of maize is likely to reduce poverty by an extra 2.4% over a period of 5 years. The poverty impact is nearly double when the new technologies are introduced simultaneously in wheat and maize sectors. At the disaggregated level, the poverty incidence declines significantly more in urban areas compared to rural settings across the three scenarios. This is because urban households benefit from positive income and price effects while rural households see their nominal income decline slightly because of lower agricultural wages and low returns to agricultural capital. This reduces the extent to which rural households are able to increase their real consumption. Furthermore, as low-income rural households are often far from the poverty line, the consumption gains are not sufficient to lift a higher share of the poor out of poverty. Indeed, the initial level of the poverty gap is higher among rural households compared to the urban households. A large change in consumption is needed for the extremely poor households in rural areas to emerge out of extreme poverty. Finally, across all scenarios, poverty reduction is slightly higher among households residing in small urban areas where the low-income households have benefited from the highest real consumption gains.

The poverty gap (depth) and severity of poverty both decline after the introduction of the promising new wheat technologies. The trend is similar to that of the poverty incidence when comparing rural and urban households across the three scenarios. When disaggregating urban areas by size, the micro simulation results show that the poverty gap index and the poverty severity index decline more in small urban areas. This is encouraging as the latter have higher poverty depth and severity rates.

The micro simulation model enables us to estimate the number of poor people lifted out of poverty for each of the three scenarios. The analysis indicates that the introduction of high-yielding and drought tolerant wheat and maize technologies leads to lifting a total of 667,205 poor people out of poverty on a cumulative basis. Improved maize technologies result in a higher impact as 438,896 poor people are lifted out of poverty compared to the wheat only scenario where 189,440 poor escape extreme poverty. Furthermore, we find that the impact tends to be less effective across time (Table 7). The first year of introduction of the new technologies results in higher poverty reduction[9]. In the joint wheat-maize

[9] Here, poverty reduction is measured through poverty incidence. We compare changes in the poverty incidence in the first year of implementation of wheat and maize technologies with the performance in the fifth year. The reference is the BAU scenario for both years.

technology scenario, 227,160 poor people are lifted out of poverty just in the first period. However, the fifth year of implementation of the new technology lifts 84,134 poor individuals out of poverty. The main reason behind such a performance pattern is the simulated productivity gains accruing from the introduction of new varieties of wheat and maize[10]. The latter allows for higher yields in comparison to the reference scenario but does not show increasing or decreasing productivity change over time. Yearly, the new varieties allow wheat productivity to be 3.9% higher while for maize, productivity is 7.1% higher.

The simulation results show that investing in wheat and maize sectors through improved and appropriate technologies could have important general equilibrium effects as these are two important staple cereals in Ethiopia. Although the changes in terms of growth and welfare impacts relative to the baseline reference scenario are relatively small, our simulation results show the potential of such technological interventions for improving growth, food security and accelerating poverty reduction in Ethiopia. Wheat and maize are important cereals for food security in Ethiopia and have the potential for improving food consumption and nutrition in the country. As major staples grown by smallholder farmers in the high altitude temperate highland regions, wheat production reached 11% of total crop output and 16% of total cereal production in Ethiopia while maize represented 19% of total crop production and 28% of total cereal production in 2010/11.

These type of technological intervention that increase productivity target rural households but tends to benefit urban inhabitants and the net buyers relatively more, primarily through price effects. To increase the impact of such policies on growth and poverty, the government may complement the adoption of improved technologies with other interventions that further enhance productivity or create employment opportunities (e.g. productive safety nets program) so as to maintain the incomes of vulnerable low-income households. This is particularly important as poverty in Ethiopia is concentrated in rural areas where most labour is employed in agricultural and allied non-farm activities. Opportunities for enhancing growth in the rural non-farm sector and investments in small and medium rural towns would create employment and expand the demand for agricultural

[10] The sources of the scope of simulations are presented in section 4.

produce. Such growth in demand prevents a fall in the income of the smallholders following productivity growth which triggers a fall in food prices.

VI. Conclusion

This paper analyzes the economy-wide impacts of agricultural productivity gains resulting from the adoption of high yielding and drought tolerant staple crop technologies (wheat and maize) in Ethiopia. A dynamic CGE model with a micro simulation model was developed. We use the standard PEP CGE model developed by Decaluwé et al (2013) in its dynamic version.

Three distinct scenarios are run to analyze the impact of introducing improved staple crop varieties (wheat and maize) in Ethiopia. The policy shocks take effect in 2015/16 which corresponds to the 6th period in the model. In the first scenario, total factor productivity (TFP) of wheat is increased by 3.9% compared to its level in the reference scenario and remains 3.9% higher across the five-year period. The crop-specific productivity change is estimated based on a crop growth model (DSSAT) which was simulated by CIMMYT based on the attributes of the promising varieties and recent research results. The second scenario which is analogous to the first one increases the TFP in the maize sector by 7.1%. The third scenario combines the first two. In the reference scenario, agricultural productivity increases annually based on performances of the agricultural sector between 2009/10 and 2014/15 and yield gains due to maintenance and research estimated by the IMPACT model.

We find that the introduction of improved varieties for staple crops (wheat and maize) is likely to boost the two cereal sectors. The growth and poverty impacts are higher when the new technology is adopted for both cereals simultaneously. GDP expands by 0.1%, 0.4% and 0.5% in the first, second and third scenarios respectively. Compared to the baseline, the poverty incidence is 3.7% lower in the third scenario while it is 1.1% and 2.4% lower in the first and second scenarios. The increased output resulting from technological change reduces domestic prices of maize and wheat. As food staples and in particular cereals represent an important share of consumption expenditure for Ethiopian households, such technologies are likely to benefit the poor. Food production overall also increases slightly showing that such technologies have the potential to reduce food insecurity by increasing supply and affordability of food crops on the local market. Lower local prices may also increase export competitiveness. Since agriculture is the main source of exports in Ethiopia, such policies which improve the productivity of food staple are likely to improve the trade balance and limit deterioration of the current account balance. Moreover, lower prices could allow for some import substitution in particular for wheat making prices less constrained by international prices.

High-yielding and drought-tolerant varieties of wheat and maize tend to benefit urban inhabitants relatively more due to positive price and income effects. Furthermore, the rural poor are often far from the poverty line with an initial level of poverty gap much higher in rural areas compared to the urban. This makes it difficult for the rural poor to escape poverty even when they benefit from technological change. Technological and policy interventions aimed at increasing or maintaining the incomes of rural households without increasing food prices are likely to result in higher agricultural growth and poverty reduction. This is important for Ethiopia as poverty is predominantly a rural phenomenon. Investment in the allied rural non-agricultural activities could particularly address the unique problems of the landless and ultra-poor households who may not directly benefit from agricultural interventions. It is important to note that technological change in maize and wheat is also only a small component of past and ongoing investments in the agricultural sector in Ethiopia. Most of these interventions aim at improving agricultural production and food security across crops through, in particular, productivity growth for smallholder farmers. Such productivity growth will progressively reduce labor requirements of agricultural activities and will release surplus labor to rural non-farm and other sectors. However, over 80% of the population still resides in rural areas and earns living from rural activities, in particular agriculture. A large proportion (72.6%) of the labor force works in agriculture and related activities. It is therefore important that, along with efforts to improve agricultural productivity, rural non-agricultural activities are given due attention as the latter will need to absorb surplus labor and reduce rural underemployment and unemployment. In summary, whereas high-yielding and drought tolerant staple crop varieties tend to generate growth and poverty reduction outcomes, the poverty impacts are not large enough and cannot be expected to move a large number of chronically poor households out of poverty. This suggest that such important interventions should not be implemented in an isolated manner but rather be part of other strategies, programs and projects to maximize the growth and poverty impacts on the rural poor in the medium to long run.

References

Abate, T., Shiferaw, B., Bogale, G., Wegary, D., Regasa, M. W., Tadesse, B., Keno, T., 2013. The Maize Revolution in Ethiopia: What Are the Lessons? DT Maize Bulletin. 2 (4, 4).

Abate, T. Shiferaw, B., Menkir, A., Wegary, D. Kebede, Y., Tesfy, K., Kassie, M., Bogale, G., Tadesse, B., Keno, T., 2015. Factors that transformed maize productivity in Ethiopia. Food Security. 7(5): 965-981.

Ayenew, M.M., 2015. The dynamics of food insecurity in Ethiopia. *International Journal of System Dynamics Application*. 4(4):17-34.

Benson, T. Engida, E., Thurlow, J. 2014. The economy-wide effects of teff, wheat and maize production in increases in Ethiopia: results of economy-wide modeling. IFPRI Discussion Paper 01366. International Food Policy Research Institute. Washington, DC.

Berhane, G.L., Mc Bride, K.T.H., Tamiru, S., 2012. Patterns in foodgrain consumption and calorie intake. In *Food and Agriculture in Ethiopia: Progress and Policy Challenges*, edited by P. Dorosh and S. Rashid, 190-216.Univeristy of Pennsylvania Press, Philadelphia.

Byerlee, D., Spielman, D.J., Alemu, D., Gautam, M., 2007. Policy to promote cereal intensification in Ethiopia: a review of evidence and experience, IFPRI Discussion Paper 00707. Development Strategy and Governance Section, International Food Policy Research Institute, Washington, DC.

COHA (Cost of Hunger in Africa), 2013. The social and economic impact of child under- nutrition in Ethiopia: summary report. The Cost of Hunger in Ethiopia: Implications for the Growth and Transformation of Ethiopia. Ethiopian Health and Nutrition Research Institute.

CSA (Central Statistical Agency), 2011. Household income and consumption expenditure survey 2010/11: analytical report and raw data. The Federal Democratic Republic of Ethiopia.

CSA (Central Statistical Agency), 2014. Agricultural Sample Survey 2009/10 to 2014/15. The federal Democratic Republic of Ethiopia.

CSA (Central Statistical Agency), 2014a. Comprehensive food security and vulnerability analysis. The Federal Democratic Republic of Ethiopia.

CSA (Central Statistical Agency), 2014b. Household consumption and expenditure survey 2010/11: analytical report. The Federal Democratic Republic of Ethiopia.

Decaluwe B, Lemelin A, Maisonnave, H., Robichaud, V., 2013. 'The PEP Standard General Equilibrium Model Single-Country, Recursive Dynamic Version PEP-1-t', Poverty and Economic Policy (PEP) Research Network. http://www.pep-net.org/uploads/media/PEP-1-t_v1_2.pdf

Dercon, S., Hill, R. V., 2009. Growth from agriculture in Ethiopia: identifying key constraints. Paper prepared as part of a study on Agriculture and Growth in Ethiopia. Department for International Development (DFID). http://users.ox.ac.uk/~econstd/Ethiopia%20paper%203_v5.pdf

Dercon, S., Zeitlin, A., 2009. Rethinking agriculture and growth in Ethiopia: a conceptual discussion. Paper prepared as part of a study on Agriculture and Growth in Ethiopia. Department for International Development (DFID). http://users.ox.ac.uk/~econstd/ethiopia%20paper%202_v2.pdf

Diao, X., 2010. Economic importance of agriculture for sustainable development and poverty reduction: the case study of Ethiopia. In: Global Forum on Agriculture. http://www.oecd.org/tad/agricultural-policies/46378942.pdf.

Diao, X., Pratt, A.N., 2007. Growth options and poverty reduction in Ethiopia- An economy-wide model analysis. *Food Policy*. 32(2):205-228.

Dorosh, P., Thurlow, J., 2009. Implications of agricultural growth on household incomes and poverty in Ethiopia: A general equilibrium analysis. Discussion Paper No. ESSP2 002, Development Strategy and Governance Division. International Food Policy Research Institute- Ethiopia Strategy Support Program 2, Ethiopia.

FAO, 2013. FAOSTAT Database on Agriculture. Food and Agriculture Organization of United Nations. http://faostat3.fao.org/.

Foster JE, Greer J and Thorbecke E (1984) 'A class of decomposable poverty measures', *Econometrica*, 52: 761-776.

Graham, J., Rashid, S., Laek, M., 2012. Disaster response and emergency risk management in Ethiopia. In (edt.), "Food and Agriculture in Ethiopia: Progress and Policy Challenges", P.A. Dorosh and S. Rashid. Chapter 9: 256-279. University of Pennsylvania Press.

ICARDA, 2013. Tackling the threat of stripe rust in Ethiopia. International Center for Agricultural Research in the Dry Areas. Retrieved December 17, 2015, from http://www.icarda.org/features/tackling-threat-stripe-rust-ethiopia#sthash.7Rr2OrID.vpEhO7cs.dpbs

IISD (International Institute for Sustainable Development), 2011. CIMMYT Introduces Climate-Resilient Crops in Ethiopia and China. Retrieved December 17, 2015, from http://climate-l.iisd.org/news/cimmyt-introduces-climate-resilient-crops-in-ethiopia-and-china/

Tafere, K. Alemayehu S. Taffesse, and Seneshaw Tamru, 2000. 'Food Demand Elasticities in Ethiopia: Estimates Using Household Income Consumption Expenditure (HICE) Survey Data.' ESSP II IFPRI Working Paper 11 April 2010

Lobell, D.B., Cassman, K.G., Field, C.B., 2009. Crop yield gaps: their impportance, magnitudes and causes. *Annual Review of Environment and Resources*. 34:179-204.

Lofgren H, Robinson, S., El-Said, .M, 2003. 'Poverty and Inequality Analysis in a General Equilibrium Framework: The Representative Household Approach', in François Bourguignon and Luiz A. Pereira da Silva (Eds.), The Impact of Economic Policies on Poverty and Income Distribution: Evaluation Techniques and Tools, World Bank and Oxford University Press, Washington, D.C. and New York, pp. 325-337

Minten, B., Stifel, D., Tamru, S., 2012. Structural transformation in Ethiopia: evidence from cereal markets. Ethiopia Strategy Support Program II Working Paper 39. Addis Ababa, Ethiopia: International Food Policy Research Institute.

Ministry of Finance and Economic Development, 2013. Development and Poverty in Ethiopia 1995/96-2010/11. June 2013, Addis Ababa Ethiopia.

Mitik, L., Engida E., 2013. 'Public investment in irrigation and training for an agriculture-led development: A CGE approach for Ethiopia.' Working Paper 2013-02. Partnership for Economic Policy, Laval University, Canada.

National Bank of Ethiopia. Annual report 2009/10 to 2013/14

Robinson, S., Strzepek, K., Cervigni, R., 2013. The cost of adapting to climate change in Ethiopia: sector-wise and macro-economic estimates. ESSP2 Discussion Paper 53.

Rosegrant, M.W. and the IMPACT Development Team, 2012. International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT): Model Description. International Food Policy Research Institute (IFPRI), Washington, D.C. Shiferaw, B. Kasssie, M., Jaleta, M., Yirga, C., 2014. Adoption of improved wheat varieties and impact on household food security in Ethiopia. *Food Security*. 44:272-284.

Shiferaw, B., Negassa, A., Koo, J., Wood, J., Sonder, K., Braun, J-A., Payne, T., 2011. Future of wheat production in Sub-Saharan Africa: analyses of the expanding gap between supply and demand and economic profitability of domestic production. Paper presented at the Agricultural Productivity-Africa Conference 1–3 November 2011, Africa Hall, UNECA, Addis Ababa, Ethiopia.

Shiferaw, B., Prasanna, B.M., Hellin, J., Banziger, M., 2011a. Crops that fed the world 6. Past successes and future challenges to the role played by maize in global food security. *Food Security*. 3:307-327.

Shiferw, B., Smale, M., Braun, H.J., Duvelier, E., Reynolds, M. and Muricho, G., 2013. Crops that fed the world 10. Past success and future challenges to the role played by wheat in global food security. *Food Security*. 5:291-317.

Shiferw, B., Kassie, M., Jaleta, M. Yirga, C., 2014. Adoption of improved wheat varieties and impacts on household food security in Ethiopia. *Food Policy*. 44: 272-284.

Spielman, D., Mekonnen, D.K, Alemu, D., 2012. Seeds, fertilizer, and agricultural extension in Ethiopia. In *Food and Agriculture in Ethiopia: Progress and Policy Challenges*, edited by P. Dorosh and S. Rashid, 190-216.Univeristy of Pennsylvania Press, Philadelphia.

Taffesse, A.S., Dorosh, P., Sinafikeh, A. G., 2011. Crop production in Ethiopia: regional patterns and changes. ESSP II Working Paper 16. Development Strategy and Governance Division, International Food Policy Research Institute, Ethiopia.

Vandercasteelen, J., Dereje, M., Minten, B., Taffesse, A.S., 2013. Scaling-up adoption of improved technologies: the impact of the promotion of row planting on farmers' teff yields in Ethiopia. LICOS Discussion Paper Series Discussion Paper 344/2013.

Von Baun, J., Olofinbiyi, T., 2007. Famine and food insecurity in Ethiopia. Case Study #7-4. Program: "Food Policy for Developing Countries: The Role of Government in the Global Food System". Cornell University, New York.

Webb, P., von Braun, J., Yohannes, Y., 1992. Famine in Ethiopia: policy implications of coping failure at national and household levels. Research Report 92. International Food Policy Research Institute, Washington, DC.

World Bank, 2014. World Development Indicators. http://data.worldbank.org/.

World Bank Group, 2015. Ethiopia poverty assessment 2014. Report No. AUS6744. Poverty Global Practice Africa Region. The World Bank, Washington, D.C.

Zeng, D., Alwang, J., Norton, G., Shiferwa, B. W., Jaleta, M., Yirga, C., 2015. Ex post impacts of improved maize varieties on poverty in rural Ethiopia. *Agricultural Economics*. 46: 1-12.

Tables

Table 1 – Impact of high-yielding and drought-tolerant varieties of wheat, maize and joint production on sectoral and aggregate GDP (% change from reference scenario in 2019/20)

	Wheat	Maize	Wheat + Maize
Total	**0.09**	**0.36**	**0.46**
Agriculture	0.22	0.76	0.99
Teff	0.09	0.13	0.22
Barley	0.07	0.12	0.19
Wheat	2.71	0.11	2.82
Maize	0.09	6.07	6.16
Sorghum	0.06	0.11	0.17
Pulses	0.09	0.14	0.23
Vegetables & fruit	0.08	0.13	0.20
Oil seeds	0.12	0.18	0.29
Cash crops	0.03	0.06	0.09
Enset	0.05	0.08	0.13
Cereal grains and other crops	-0.02	0.00	-0.02
Coffee	0.08	0.12	0.20
Livestock	0.09	0.15	0.24
Forestry & fishery	0.05	0.09	0.14
Industry	-0.02	-0.02	-0.04
Agro processing	-0.05	-0.12	-0.17
Other manufacturing	-0.01	-0.01	-0.02
Other industry	-0.01	-0.01	-0.03
Services	0.003	0.01	0.01

Source: Simulation results from CGE model

Table 2 – Impact of high-yielding and drought-tolerant varieties of wheat and maize on household nominal income by source of income (% change from reference scenario in 2019/20)

Households	Wheat				Maize			
	Labour	Capital	Transfers	Total	Labour	Capital	Transfers	Total
Rural low-income	-019	-0.01	-0.12	-0.13	-0.28	-0.04	-0.25	-0.20
Rural high-income	-0.18	-0.01	-0.12	-0.07	-0.27	-0.03	-0.25	-0.11
Small urban low-income	0.03	0.03	-0.12	0.03	0.01	0.02	-0.25	0.01
Big urban low-income	0.03	0.03	-0.12	0.03	0.01	0.02	-0.25	0.01
Small urban high-income	0.03	0.03	-0.12	0.03	0.01	0.02	-0.25	0.01
Big urban high-income	0.03	003	-0.12	0.03	0.01	0.02	-0.25	0.01

Source: Simulation results from CGE model

Table 3 – Impact of high-yielding and drought-tolerant varieties of wheat and maize on household real consumption by aggregate product (% change from reference scenario in 2019/20)

Households	Wheat				Maize			
	Agricultural	Industrial	Services	Total	Agricultural	Industrial	Services	Total
Rural low-income	0.25	-0.04	-0.09	0.17	1.59	-0.02	-0.09	1.17
Rural high-income	0.30	0.00	-0.05	0.20	1.53	0.02	-0.05	1.05
Small urban low-income	0.44	0.10	0.03	0.31	1.08	0.11	0.03	0.72
Big urban low-income	0.35	0.09	0.02	0.21	0.48	0.09	0.01	0.28
Small urban high-income	0.37	0.07	0.01	0.18	0.59	0.08	001	0.27
Big urban high-income	0.30	0.06	0.01	0.11	0.27	0.06	0	0.09

Source: Simulation results from CGE model

Table 4 - Impact of high-yielding and drought-tolerant varieties of wheat, maize and joint production on household total nominal income (% change from reference scenario in 2019/20)

Households	Wheat	Maize	Wheat + Maize
Rural low-income	-0.12	-0.2	-0.33
Rural high-income	-0.06	-0.11	-0.18
Small urban low-income	0.02	0.01	0.04
Big urban low-income	0.02	0.01	0.04
Small urban hig-income	0.03	0.01	0.04
Big urban high-income	0.02	0.01	0.04

Source: Simulation results from CGE model

Table 5 – Impact of high-yielding and drought-tolerant varieties of wheat, maize and joint production on household real total consumption (% change from reference scenario in 2019/20)

	Wheat	Maize	Wheat + Maize
Rural low-income	0.16	1.17	1.33
Rural hig-income	0.20	1.05	1.26
Small urban low-income	0.29	0.72	1.03
Big urban low-income	0.20	0.28	0.49
Small urban high-income	0.17	0.27	0.44
Big urban hig-income	0.10	0.09	0.20

Source: Simulation results from CGE model

Table 6 – Impact of high-yielding and drought-tolerant varieties of wheat, maize and joint production on poverty by type of household (cumulative % in 2019/20) change from reference scenario in 2015/16

	National	Rural	Urban	Small urban	Big urban
			Wheat		
P0	-1.06	-0.91	-2.73	-2.97	-2.35
P1	-0.93	-0.78	-3.27	-3.56	-2.82
P2	-0.91	-0.78	-3.41	-3.65	-2.99
			Maize		
P0	-2.43	-2.12	-6.65	-8.16	-4.45
P1	-2.82	-2.62	-5.78	-6.28	-5.07
P2	-2.79	-2.59	-6.26	-6.82	-5.32
			Wheat + Maize		
P0	-3.7	-3.12	-11.09	-12.26	-9.38
P1	-3.75	-3.39	-9.01	-9.8	-7.84
P2	-3.69	-3.37	-9.63	-10.44	-8.27

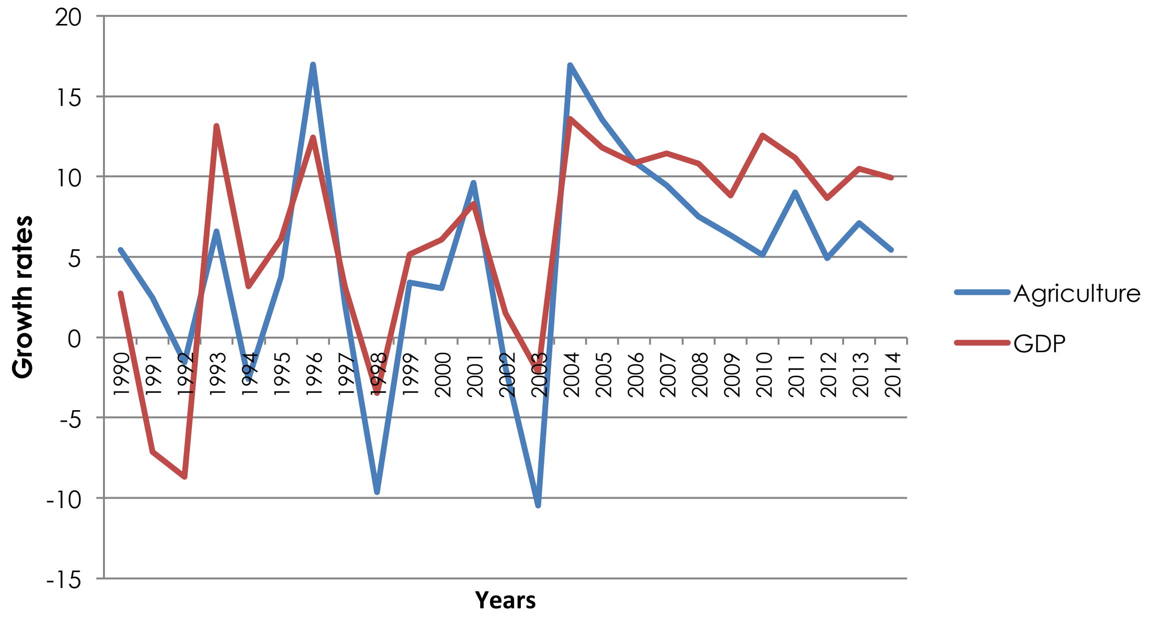
Source: Simulation results from micro simulation model

Table 7 – Impact of high-yielding and drought-tolerant varieties of wheat and maize on poverty reduction in the first, third and fifth years of implementation (% change from reference scenario in 2015/16, 2017/18 and 2019/20)

	1st year	3rd year	5th year
Poverty incidence	-1.22	-0.82	-0.48
Number of poor lifted out of poverty	227,160	145,175	84,134

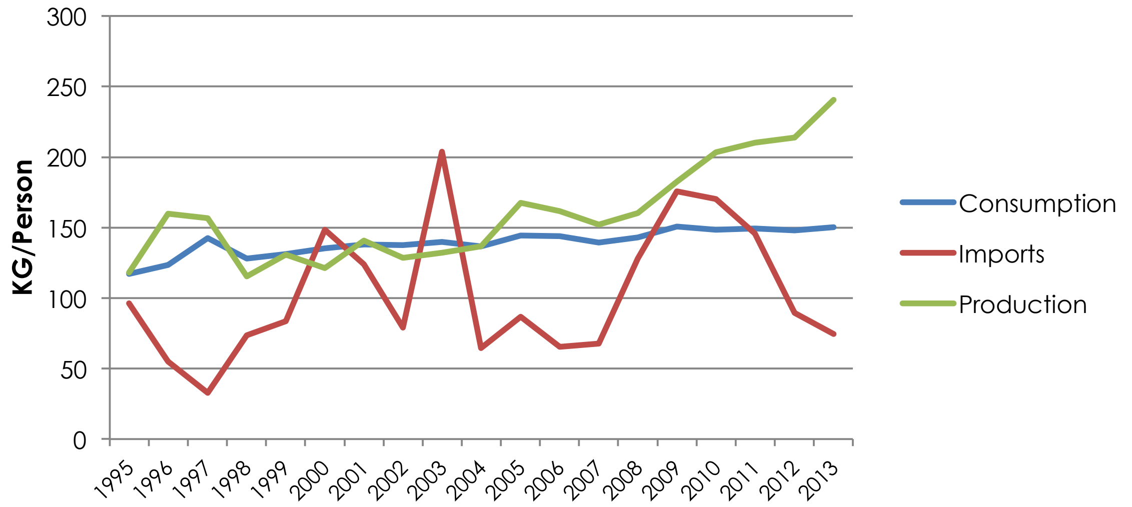
Appendix

Figure 1: GDP and agricultural growth in Ethiopia (annual %)



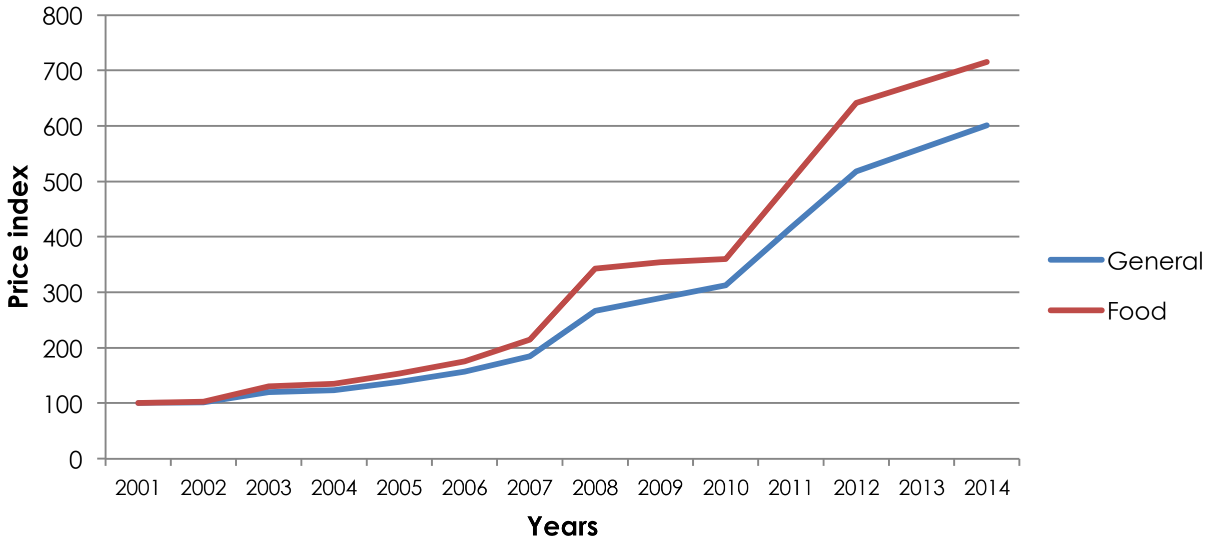
Source: World Bank, 2014

Figure 2: Per capita production, consumption and imports of food crops in Ethiopia from 1995-2013



Source: FAO, 2013

Figure 3: Consumer price index in Ethiopia



Source: FAO, 2013

Table A1: Estimated yield advantage from promising maize and wheat cultivars

Maize	**Yield advantage of drought-tolerant maize (%)**	**Yield advantage of drought-tolerant maize (kg/ha)**
Irrigated	7.14	210.38
Rainfed	7.14	129.35
Wheat	**Yield advantage of heat-tolerant wheat (%)**	**Yield advantage of drought-tolerant wheat (%)**
Irrigated	0.02	0.10
Rainfed	0.02	3.95

Source: authors' computations for maize; results from geo-spatial crop modelling with DSSAT for wheat