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Trade liberalisation in Kenya: A modelling linkage for wheat and maize

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Abstract

Kenya has become a driving force of trade integration at the regional and continental level, albeit that this process is still incomplete. Kenya was the first nation, along with Ghana, to ratify the African Continental Free Trade Area (AfCFTA) agreement in May 2018, as it was already engaged with its main trading partners. Trade policy can generate mixed effects across the economy and within the agricultural sector, reflecting differences between markets and commodities. In this paper we argue that a mix of modelling approaches is preferable in order to capture the complexities of these changes. A dynamic-recursive computable general equilibrium model provides broad sectoral and macro-economic effects, which are then incorporated into a partial equilibrium framework for a detailed analysis at the sector level. We demonstrate this using the maize and wheat markets in Kenya as examples. Combining the output of each modelling approach allows the analysis to explicitly include certain characteristics of single markets, particularly regional trade relationships and differences in pricing structure that would be missed by using a single approach in isolation. It shows that further intra-African trade liberalisation will affect wheat markets more than maize in Kenya but, given the low initial tariff levels, the ultimate effects will remain fairly small.

Key words: modelling linkage; trade; maize; wheat; Kenya

1. Introduction

Kenya is embracing regional and future continental trade integration. It already has access to the East African Community (EAC) single market and the Common Market for Eastern and Southern Africa (COMESA) free trade area.[1] This is critical, given that most of intra-African trade occurs between countries that are part of the same regional integration initiative. Thus, 99% of Kenya's intra-African trade is potentially covered by a trade arrangement (UNECA *et al*. 2017). On the other hand, Kenya (with Ghana) was the first country to ratify the agreement setting up a promising African Continental Free Trade Area (AfCFTA), which was formally established in March 2018. AfCFTA is one of the flagship projects of Agenda 2063, a strategy for the sustainable development and economic growth of the African continent, adopted by the African Union in January 2013. Fostering regional integration, boosting intra-African trade and enhancing Africa's trading position in the global market are clear objectives of this continental strategy. Lastly, Kenya has also entered into a series of trade arrangements with developed countries, such as the EU (through the Economic Partnership Agreement (EPA) between the EU and EAC) and the USA (upcoming negotiations on a bilateral deal to replace the African Growth and Opportunity Act, AGOA).

Agriculture represents a significant part of the Kenyan economy, accounting for about one fourth of the GDP and three fourths of employment. In 2020, the sector grew by 4.8%, despite short rains and reduced demand from restaurants and learning institutions, which closed as a result of the COVID-19 pandemic (Kenya National Bureau of Statistics [KNBS] 2021). Maize is the major staple crop, followed by rice and wheat. In particular, maize is the major staple crop for almost all urban consumers in Kenya (De Groote & Kimenju 2012). Wheat consumption is increasing, and most wheat is imported. The production and demand for both wheat and maize are expected to continue increasing due to population growth, the rise in per capita incomes and changes in diet. However, growth rates will differ, mostly because of differences in maize and wheat value chains, trade patterns and ecological constraints such as land degradation, water scarcity and climate change (Grote *et al*. 2021). This makes the modelling of wheat and maize markets critical for any rigorous policy analysis. Major challenges for the Kenyan agricultural sector consist of addressing low productivity, inefficient markets and low levels of value added with growing resource constraints. Kenya has adopted a strategy of trade liberalisation, but commodities deemed sensitive are often protected by tariffs and trade restrictions. Maize imports are typically procured within the region, mostly from Uganda and Tanzania. Wheat imports are not usually sourced from Africa but instead come from the world market, in particular from the Black Sea region (ReNAPRI 2015).

The purpose of the paper is to use trade policy reforms for the Kenyan maize and wheat sectors as examples of how the combination of two different modelling approaches can help to determine the complex outcomes of policy changes. Specifically, a narrow sectoral approach misses the important cross-economy effects in a country such as Kenya, where the agricultural sector is of key importance. However, sectoral models can include more detailed specifications that capture critical features of the markets themselves. Here it is argued that there are differences in the wheat and maize markets that lead to different effects of similar policy changes. Linking a partial and a general equilibrium model allows us to capture some of these specificities.

[1] Regional economic integrations are dynamic and still incomplete. The EAC (six member states) contemplates the implementation of a free trade area, customs union and single market, whereas COMESA (21 member states) is limited to a free trade area. To get an overview of the latest progress with and scope of Africa's regional integration initiatives, please refer to the Africa Regional Integration Index, developed by the African Union, the United Nations Economic Commission for Africa and the African Development Bank (https://www.integrate-africa.org/).

The paper is structured as follows. Section 2 details the modelling frameworks. Section 3 provides a market outlook for the maize and wheat sectors in Kenya. Section 4 presents two trade policy reform scenarios and discusses the modelling results. Section 5 concludes.

2. Modelling framework

To simulate further market liberalisation, the paper links the outcomes of a partial equilibrium (PE) model and a single-country dynamic-recursive computable general equilibrium (CGE) model. Although both models are designed for policy analysis, their structure and operation differ considerably. In addition to the actual mechanical operation, the two are representative of two alternate modelling approaches. Coincident simulation of these two models is not possible – given their different structures – but it is possible to incorporate outcomes from one model simulation into the other. For example, the CGE approach produces estimates of policy impact on the macro-variables that are exogenous to the PE model. This section presents the theoretical and empirical foundations of both modelling approaches, as well as their linkages. A brief literature review on existing attempts to connect both approaches is also provided.

2.1 Partial equilibrium modelling

The PE model comes from the Regional Network of Agricultural Policy Research Institutes' (ReNAPRI) system for the agricultural sectors of southern, eastern and central African countries. It has been developed in part using the approach of the Food and Agriculture Policy Research Institute (FAPRI) (Meyers *et al*. 2010).[2] The models are used either separately or together to produce simulations of policy changes or important issues, such as the impact of drought, for the region (ReNAPRI 2017). The details of these models vary by region and by commodity, with the aim of the PE approach being to capture the main differences inherent in the industries. The Kenyan module within the ReNAPRI system presently includes maize and wheat, two crops playing a critical role in food security (Grote *et al*. 2021). Differences in trade patterns and price formation, however, require different modelling approaches for maize and wheat.

2.1.1 PE model structure for the Kenyan maize sector

Maize markets in Eastern and Southern Africa are typically regional, with the non-genetically modified white maize mostly consumed in the region, differentiated somewhat from the yellow maize traded in the global market. As such, markets are fairly isolated from the global context, and integration in the world market is typically weak. Trade occurs mostly within the region and, while price transmission from global markets is weak (Minot 2011; Baquedano & Liefert 2014; Davids *et al*. 2017), various regional markets reflect co-integrated relationships (Davids *et al.* 2017; Davids 2018). In order to capture regional price relationships, the Kenyan maize model is linked to that of the rest of the region through a system of intra-regional trade, as illustrated in Figures 1 and 2.

Within the domestic supply block, area is determined by the returns to the sector, along with those for crops that compete with maize for land, such as wheat (Figure 1). Returns are the market returns (yield multiplied by price) deflated by an index of input costs. Input costs include fuel, fertiliser and seed prices. The imposed elasticity of area with respect to returns is 0.15, which is in line with previous findings that have suggested that the supply response in the agricultural sectors in the region is inelastic (Magrini *et al*. 2018). While some regional studies have reported elasticities slightly higher than 0.15, Olwande *et al*. (2009) evaluated Kenyan maize farmers' responsiveness to price and non-

[2] Details of the partial equilibrium model for Kenya that is part of this system and used in this research are provided in Appendix 1.

price factors, reporting elasticities of 0.11 for maize prices without explicitly accounting for cross-price effects, and -0.06 for fertiliser prices. Yields are estimated using a trend yield that is based on the historical growth in yields, returns to the sector, as well as total area. A positive increase in returns has a positive impact on yields, whereas a positive increase in area has a negative impact on yields. Nonetheless, the main determinant of yields comes from the trend variable, which also incorporates the historical rate of technological gains.

The demand for maize is disaggregated into food and feed use. Food use is modelled on a per capita basis and is determined as a function of income and prices. The imposed price elasticity of the food use of maize relative to its price is -0.3. The income elasticity of food consumption is an important driver of the model, given the relatively strong income growth projected. In the model it is 0.03. Consumption therefore rises with income, but at a low rate, given that maize is a basic food staple. The rate is lower than that of wheat, which is what we would expect given consumption patterns in recent years. Population growth will mean that, in the absence of a large negative income elasticity, maize consumption will continue to grow.

Feed demand is hard to estimate in many sub-Saharan countries, given that data are poor and the sectors generally do not have highly feed-intensive systems. In the case of the ReNAPRI model, there is no livestock model yet from which to derive demand for feed. Instead, a simplified assumption is made about the growth of the livestock sector, based on historical trends. An index of feed demand per animal is calibrated using meat and dairy production levels, and this assumes feed conversion ratios. This produces a feed per head that can then be used to determine maize feed. In reality, this is one area where there is great uncertainty – growth in meat production could come with intensification and an increase in feed per head. Ideally, livestock models could be part of the ReNAPRI framework in the future.

Trade is included through a bilateral system. Export equations for each of the other countries included in the ReNAPRI model are based on a spatial equilibrium-type specification detailed in Davids *et al*. (2018). The specification includes an arbitrage-correcting parameter that becomes more elastic beyond a specified threshold. Imports are determined in a similar fashion to exports from partnering countries. Imports from the rest of the world are based on arbitrage derived from the world price.

Prices are determined as a function of total supply and total demand, with trade linking the sector to world and regional prices. Prices therefore are the result of the solution obtained from the entire system of equations. The flow diagram in Figure 2 details the trade-price solution in the modelling structure. For simplicity, and to enable illustration of the system, the flow diagram includes only three countries, although all nine ReNAPRI member countries are included in the modelling system (i.e. Democratic Republic of Congo, Kenya, Malawi, Mozambique, South Africa, Tanzania, Uganda, Zambia and Zimbabwe).

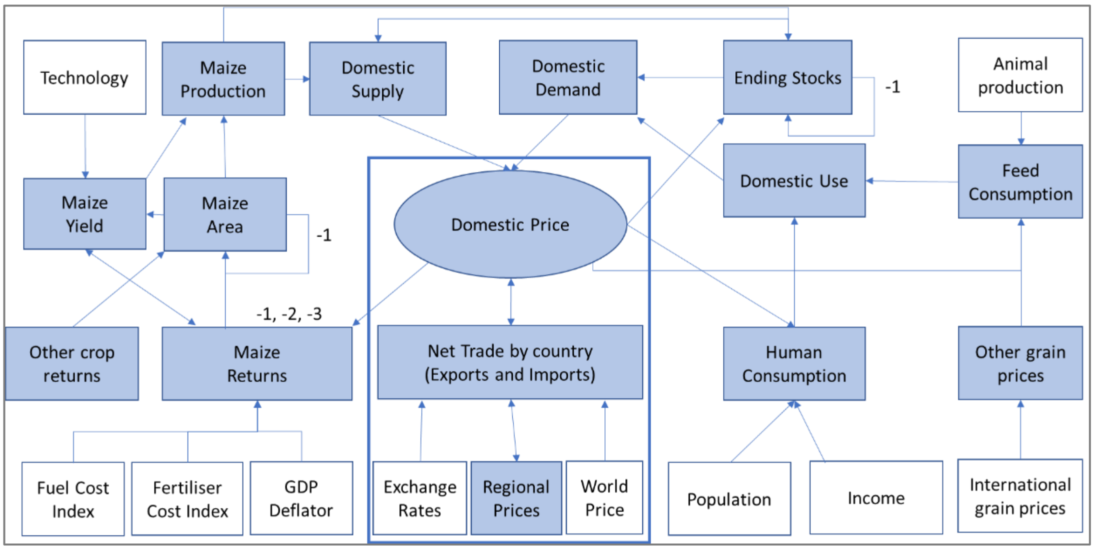

Figure 1: Flow diagram of the Kenyan maize model

Note: -*i* indicates a lag of *i* years; coloured boxes represent endogenous variables; white boxes represent exogenous variables. Source: Davids *et al*. (2018)

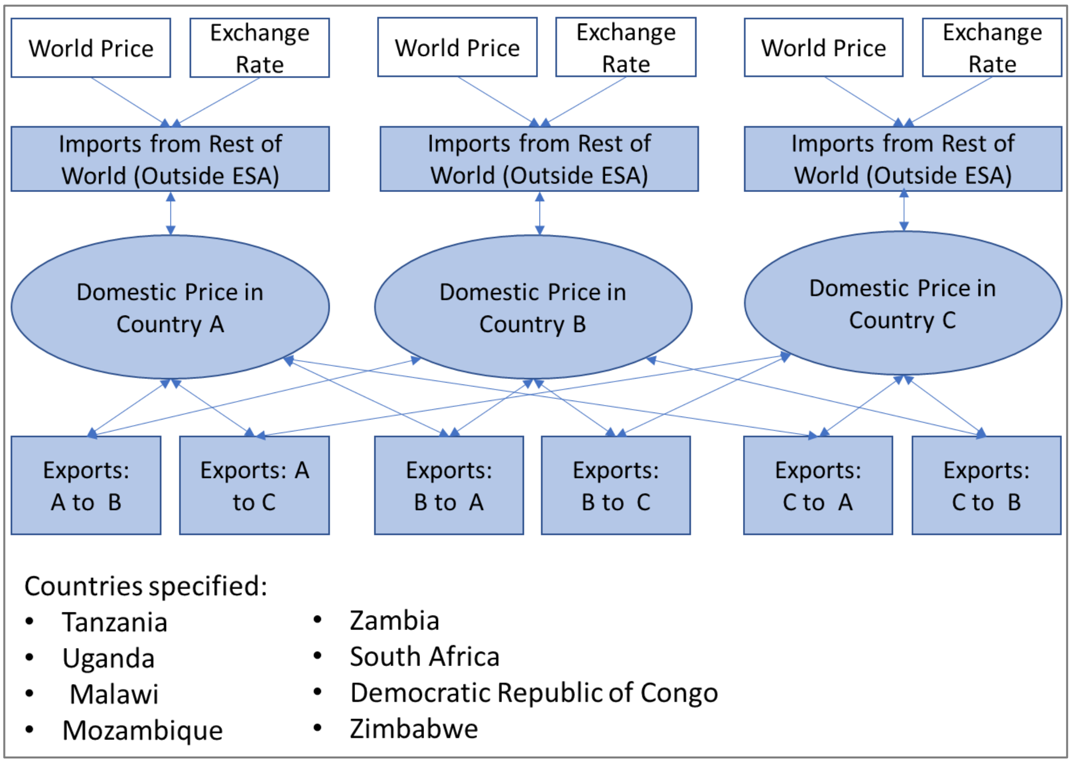

Figure 2: Flow diagram of the effect of trade on the price solution

Source: Davids *et al.* (2018)

2.1.2 Structure of the PE model for the Kenyan wheat sector

In contrast to maize, the bulk of Kenya's wheat imports originate from outside eastern and southern Africa, and prices are significantly influenced by world markets. As such, the model is structured differently from that of maize, with prices determined as a function of world price movements, adjusted for tariffs and the exchange rate relative to the US dollar. Model closure is achieved through an import identity (Figure 3). Kenyan wheat prices are estimated using world wheat prices converted to Kenyan shilling, taking account of the tariff. The estimated coefficient on the adjusted world price variable is 0.83, meaning that 0.83 of every change in that price is passed on to the Kenyan wheat price. This is much higher than the pass-through of the world maize price into the domestic market, which is passed through the regional model. The figure above is similar to the most recent estimate in the literature of the price transmission elasticity from international to domestic wheat markets in Kenya, of 0.78 (Kipruto 2019). In the price linkage equation, a self-sufficiency variable is included so that there is some effect of changes in domestic production and consumption on prices, although the elasticity of this variable is low. This means that domestic prices can move differently to world prices under certain circumstances, but in general they move together.

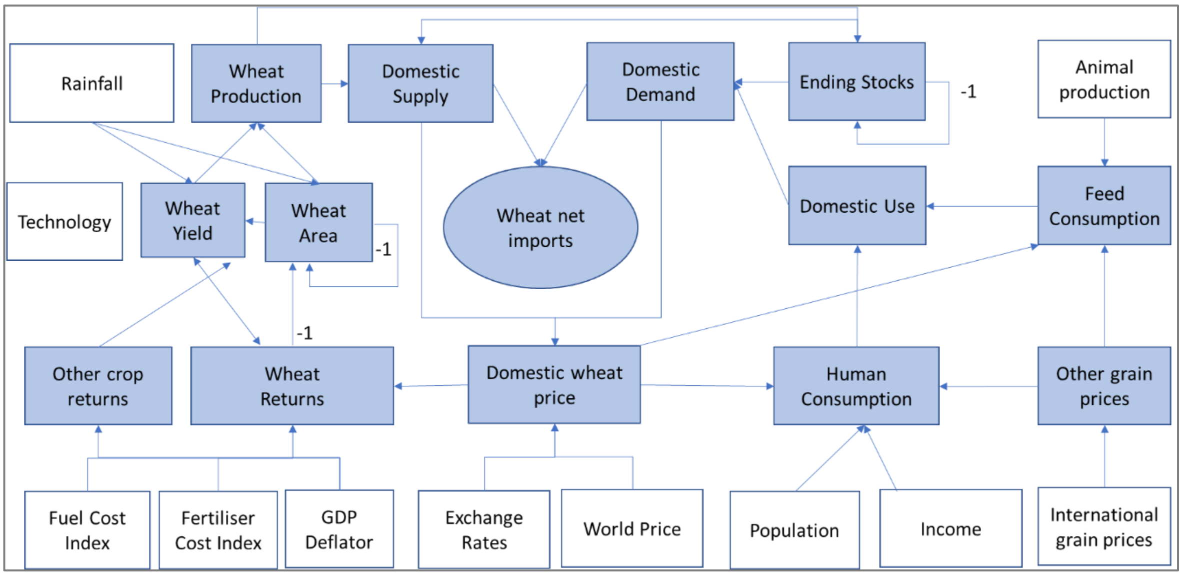

Figure 3: Flow diagram of the structure of the Kenyan wheat model

Note: -*i* indicates a lag of *i* years; coloured boxes represent endogenous variables; white boxes represent exogenous variables.

The domestic supply and demand specification is similar to that of maize. Area is determined as a function of real prices of wheat and sorghum, determined to be the crop that competes most with wheat for area. The elasticity of area with respect to the real wheat price was estimated at 0.22. Also included in the equation is a rainfall variable. Yields are estimated using a trend yield that is based on the historical growth in yields and the real wheat price. The elasticity of yield with respect to wheat price that comes from the estimated equation is high, at 0.68.

Demand is disaggregated into food and feed use. The feed use of wheat is an insignificant part of overall consumption and is held exogenous. Food use is modelled on a per capita basis and is determined as a function of income and prices of both wheat and alternative cereals. The estimated own price elasticity of food consumption is -0.25, and the estimated income elasticity is 0.34. This elasticity is higher than for maize in the light of a growing shift towards wheat consumption in many Kenyan cities (Jayne *et al*. 2010). In the scenarios this is an important driver of results.

2.2 General equilibrium modelling

The CGE model used in this paper is built upon a single-country static applied computable general equilibrium (STAGE) model designed to address developing country-specific issues (Aragie *et al*. 2016) that incorporates behavioural relationships that better account for economic relationships in developing countries. The STAGE-DEV model has been enhanced to review policy options supporting the Agriculture Sector Growth and Transformation Strategy (ASGTS) of the Kenyan government (Boulanger *et al*. 2018) and to evaluate the effects on food security of expanding fertiliser capacities in Kenya (Boulanger *et al*. 2022). STAGE-DEV follows the assumptions of a small open economy (domestic price changes do not affect world prices) and of perfect competitions (prices and quantities are not subject to market power on the supply or demand side).

STAGE-DEV accounts for the non-separability of the dual role of subsistence farmers as producers and consumers (the household production for household consumption (HPHC) approach). These farmers allocate labour and capital to produce their own consumption. Explicitly modelling household production, consumption and factor supply requires adjusting household factor supply and market clearing conditions and constraining the factor use in the own production activity through factor endowment. Subsistence producers are modelled as multiple-output activities, with the composition of output varying in response to changes in the relative prices of commodities through a constant elasticity of transformation (CET) function. The model adopts a flexible production function for agricultural activities, assuming imperfect substitution between intermediate inputs, labour, capital and land composites, through a series of nested constant elasticity of substitution (CES) functions. Intermediate inputs (including seeds) display a perfect complementarity nesting using a Leontief production function. For seeds, household-produced and commercial seeds (i.e. bought from market) are imperfect substitutes at a lower-level nest, assuming a CES function nesting. Different labours (i.e. skilled, semiskilled and unskilled) and capital (i.e. agricultural capital and livestock) are imperfect substitutes, allowing producers to switch to less expensive labour or more productive labour or capital types. Consumption is modelled through a linear expenditure system (LES), where households maximise their utility subject to a Stone-Geary utility function. In this function, household consumption demand consists of two components: ‘subsistence’ demand and ‘discretionary’ demand, where consumption responses to shocks depend both on the initial level of consumption recorded in the social accounting matrix (SAM) and on the estimated elasticities of each household’s income (Vigani *et al*. 2019). It is worth mentioning that consumption preferences do not change over time as incomes evolve.

Macroeconomic closure rules are as follows. Factors are fully employed. The fixed supply of labour holds at the national level, while the regional supply is updated to reflect changes due to migration. Land is mobile across agricultural activities within each region (see below). The exchange rate adjusts to keep the foreign savings at the level of the base year and to avoid any additional creation of liabilities. Government savings are fixed, and government spending adjusts to accommodate change in government income.

To calibrate this model, an SAM for Kenya (base year 2014) was estimated with an original structure (Mainar-Causapé *et al*. 2018, 2020). This matrix is consistent with national statistics and was estimated from national accounts and microdata from the 2005/2006 Kenya integrated household budget survey (KIHBS). Modelling HPHC involves expanding the structure of an SAM, including extra commodities valued at basic prices (excluding margins and sales taxes), while marketed commodities are valued at purchaser/market prices (including margins and sales taxes). For this reason, the 2014 SAM for Kenya deviates from standard matrices. The classic representative household groups (RHG), which gather household behaviour as consumers of goods and services and as providers of factors of production, show the behaviour of households as units of production of commodities. These accounts incorporate the economic behaviour of households as producers of food commodities (agricultural and livestock products), as well as of cash crops. This requires separate accounts for commodities produced by these households for own consumption, and other marketed commodities.

The Kenyan agricultural sector is split into six regions plus Nairobi and Mombasa, which are the two largest metropolises. The considered regions (high rainfall, semi-arid North, semi-arid South, coast, arid North and arid South) reflect different agricultural production characteristics and cost structures. The spatial breakdown also applies to households as productive and institutional units. Households as institutions are disaggregated into rural and urban according to the area of residence. Furthermore, in both Nairobi and Mombasa, households are disaggregated by quintiles of income.

Table 1 summarises the main differences in the PE and CGE modelling structure and operation.

Table 1: Characteristics of the modelling framework

	Partial equilibrium	**General equilibrium**
Type	System of single equations, dynamic	Recursive, dynamic
Parameters	Mixture of estimation, calibration	Calibrated using SAM for 2014
Coverage	Wheat and maize	Multi-sectoral, multi-commodity
Production	Three single equations per commodity	Nested constant elasticity of substitution
Consumption	Single equations for feed and food use	Nested constant elasticity of substitution
Trade	Identity for wheat, spatial model for maize	Two-level Armington

2.3 Linking partial and equilibrium modelling approaches

The literature proposes some attempts at linkage between partial, especially FAPRI, and CGE models. In Hubbard *et al*. (2018), CGE and UK-FAPRI models are linked to estimate macro-, sector- and farm-level effects for UK agriculture of various policy scenarios linked to the exit of the UK from the EU. Recent studies include the use of the Modular Applied GeNeral Equilibrium Tool (MAGNET), a global CGE model, combined with the Aglink-Commodity Simulation Model (AGLINK-COSIMO) PE system, to capture the complexity of analysing multiple trade agreements at the same time, along with the details needed to explore the effects on the agricultural sector in the EU. Both models are linked through a sequential chain implementation, where MAGNET provides trade-flow changes fed into AGLINK-COSIMO, which translate this new trade reality into the EU agricultural market balances and prices (Boulanger *et al*. 2016; Ferrari *et al*. 2021).

Given the plethora of models that operate under the umbrella of CGE and PE models, the potential for linking them is substantial, and the last decade has seen an increase in the connection of the systems. Delzeit *et al*. (2020) compare approaches of linking CGE models in the context of baseline calibration procedures, and provide suggestions for best practices. All models are 'partial' to some extent, and a CGE model can be rendered as a PE model by simulating certain sectors in isolation. The utilisation of the disaggregated nature of PE models for sectoral analysis has been a motivation for linking other modelling systems, such as the CGE Global Trade Analysis Project (GTAP) model to partial equilibrium models (Narayanan *et al*. 2010). The ability to represent trading arrangements such as tariff rate quotas more closely is a solid motivation for linking models (Grant 2007). To assess some potential effects for UK agriculture derived from Brexit, Hubbard *et al*. (2018) use the simplest way of linking the different models, viz. by using the output of one modelling approach in the other. In this case, the PE model is able to analyse the agricultural sector in a more disaggregated way, which is critical given the significant influences of Brexit on agriculture.

Existing research works that link the PE and CGE models, usually to combine the higher level of disaggregation of a PE model with the wider scope of the CGE model, feature a range of alignments of datasets or behavioural parameters. Examples of the integration of datasets are the AgroSAM/ BioSAMs datasets, which correspond to SAMs and comprise detailed disaggregation of the agricultural/bio-economy sectors that can be used in CGE models, but still have the disaggregation necessary for partial equilibrium models (Müller *et al*. 2009; Mainar-Causapé & Philippidis 2018). Increased integration of the behavioural parameters of the model is another approach that has been pursued. An example of this approach is the CAPRI modelling system (Britz & Witzke 2014) linking regional CGE models with special multi-commodity models. The PE and GCE models used in this research were created by different institutions and for different purposes, thus impeding their integration. Data requirements for a CGE and PE model are very different, e.g. CGE models need vast amounts of data that can only be updated infrequently, whereas PE models, such as the ReNAPRI model, need to be updated at least annually. Also, the ReNAPRI model needs projections of exogenous variables. Similarly, parameter alignment is not possible, since the structures of the models are different. Although both have 'supply' and 'demand', the parameters on the actual equations are not comparable. The integration of the modelling frameworks involves a series of trade-offs. One of these is in relation to the resources needed to accomplish it, which can be substantial. The second involves the inevitable changes to one or both of the models in order to make them consistent. In the case of this paper, the costs of integration are high, and part of the reason for the research was to take advantage of the different characteristics of the models. This comes at a cost in terms of the consistency of the results, and in this paper we attempt to make clear the steps that are taken and the implications for the interpretation of the results. Future work could further investigate the integration possibilities and the sensitivity analysis of the parameters.

3. Kenyan maize and wheat sector outlook

Maize imports from the EAC and COMESA are subject to an import declaration fee of 2.75%, while maize from the rest of the world is charged a 50% ad valorem duty. Traditionally, the government waives this duty to allow imports when the country experiences a major shortfall in production (Gitau & Meyer 2018). However, following the implementation of a ban on genetically modified foodstuff, implementation has been more consistent since 2012, with the facilitation of imports from the EAC prioritised over the waiving of MFN duties (ReNAPRI 2015). This policy dynamic is expected to continue.

Furthermore, the government influences maize market prices through the National Cereals and Produce Board (NCPB) by offering above-market prices at harvest time whilst selling at below market prices at other times in the season (Gitau & Meyer 2018). Sometimes, millers shun maize from the NCPB because of poor quality due to poor storage. Wheat is the second most important staple crop after maize; however, Kenya exhibits a structural deficit of approximately 70% of total demand, which is covered through imports. Import duties within the EAC and COMESA region amount to 10%, whereas a duty of 35% is applied to imports from the rest of the world. Wheat products are imported duty free if they conform to the rules of origin of both the EAC and COMESA. In Kenya, wheat production is highly mechanised and input intensive, making it uncompetitive for small-scale farmers. Consequently, the government requested a moratorium from COMESA on the 35% ad valorem import duty on wheat grain from 2002 to 2005 in order to allow time to address challenges in the wheat sector to make it more competitive. At the end of the moratorium, an extension was requested, which was subsequently granted until June 2010. At the expiry of the moratorium, import duties reverted to 35% on an MFN basis, although they were effectively 10% for registered millers and duty free within COMESA and the EAC (Gitau *et al*. 2010).[3]

Even with the duty, imported wheat is priced more competitively than domestically produced wheat. Government supports farmers by requiring importers (millers) to import only after exhausting domestic supply. However, wheat farmers are lobbying for an increase in the duty to make their wheat locally competitive. On the other hand, millers have been pushing for the wheat to be zero rated to lower the cost of wheat flour for consumers. According to millers, wheat grain accounts for between 55% and 65% of the cost of milled flour. Since the financial crisis in 2009, the Kenyan economy has expanded rapidly, at an average pace of 5.5% a year (Figure 4), helped by prudent macro-economic policies. In 2017, real GDP growth fell below 5% due to subdued credit growth in the midst of caps on commercial bank lending rates, effects of the drought on agriculture, and prolonged uncertainty related to the presidential election. Kenya's economy has been affected by the COVID-19 pandemic,

[3] The tariff is 35%, but government gives importers a rebate of 25%.

with a growth rate falling from 5.0% in 2019 to -0.3% in 2020. However, East Africa seems to be the most resilient region, and Kenya the top performer (after Djibouti), thanks to less reliance on primary commodities and greater diversification. In 2021, GDP growth was expected to recover its path growth, at 5.4%, supported the most by agriculture (AfDB 2021). Over the last decade, expansionary fiscal policy has focused on large infrastructure projects and continued investment, coupled with improvements in the business environment. The International Monetary Fund (IMF) expects the economy to keep growing at between 5.6% and 6% per year, although rapid population growth translates into a lower percentage on a per capita basis.

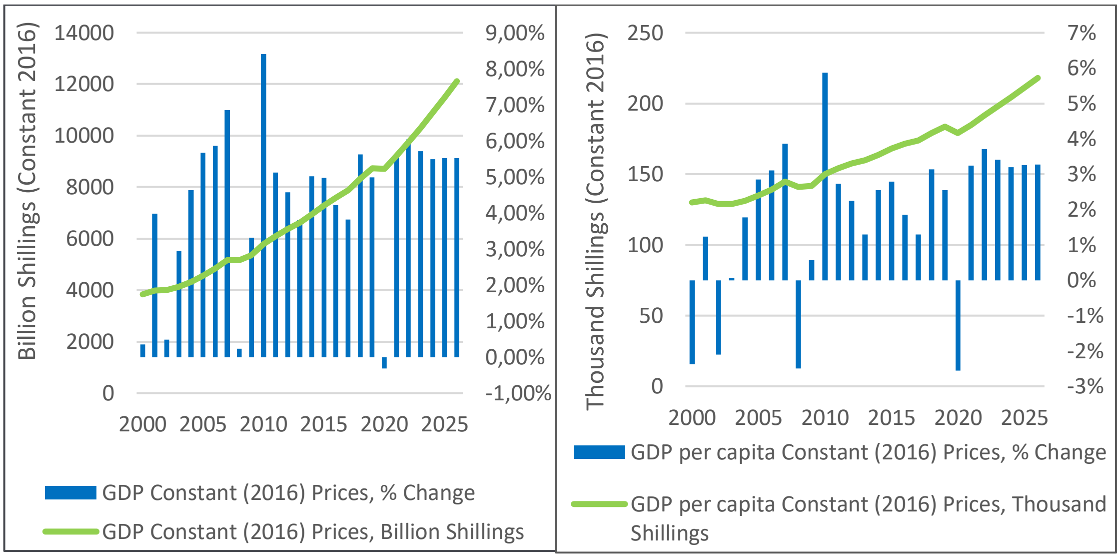

Figure 4: Growth in real gross domestic product (GDP) in Kenya

Note: Total (left) and per capita (right) terms. Source: IMF World Economic Outlook 2021 (AfDB 2021)

Between 2005 and 2019, the Kenyan population expanded by about one third, from 36 million people to 47 million people, i.e. an average annual rate of expansion of 2.7%. The United Nations expects this trend to continue, with the total population projected to reach 60 million by 2025. The share of the population residing in urban areas has also increased significantly, and will continue to increase (Figure 5). The increase in the rate of population growth is strong enough, however, that even with rapid urbanisation, the population in rural areas will also increase. This is reflective of the expectations for many of the other countries in sub-Saharan Africa. Population growth will play a central role in the evolution of the agricultural sector. It will result in a significant increase in the demand for food, particularly given the youthful demographic of the coming population, shown in part in the increase in wheat consumption.[4]

[4] In the PE model, population is taken exogenously under the baseline from the UN World Population Prospects. Under the scenarios, the same percentage changes modelled in the CGE framework are applied to the PE simulations. Under the baseline scenario in the CGE model, the population growth is also taken exogenously from the UN World Population Prospects. The population then becomes endogenous under the policy scenarios. Population changes are a function of the evolution of birth and death rates. Both demographic variables are endogenous in the model. Birth rates are determined as an inverse function of education spending on a per capita basis, and death rates are an inverse function of health spending per capita (Boulanger *et al*. 2018). Government expenditure on both education and health is taken from FAO Monitoring and Analysing Food and Agricultural Policies (MAFAP) database.

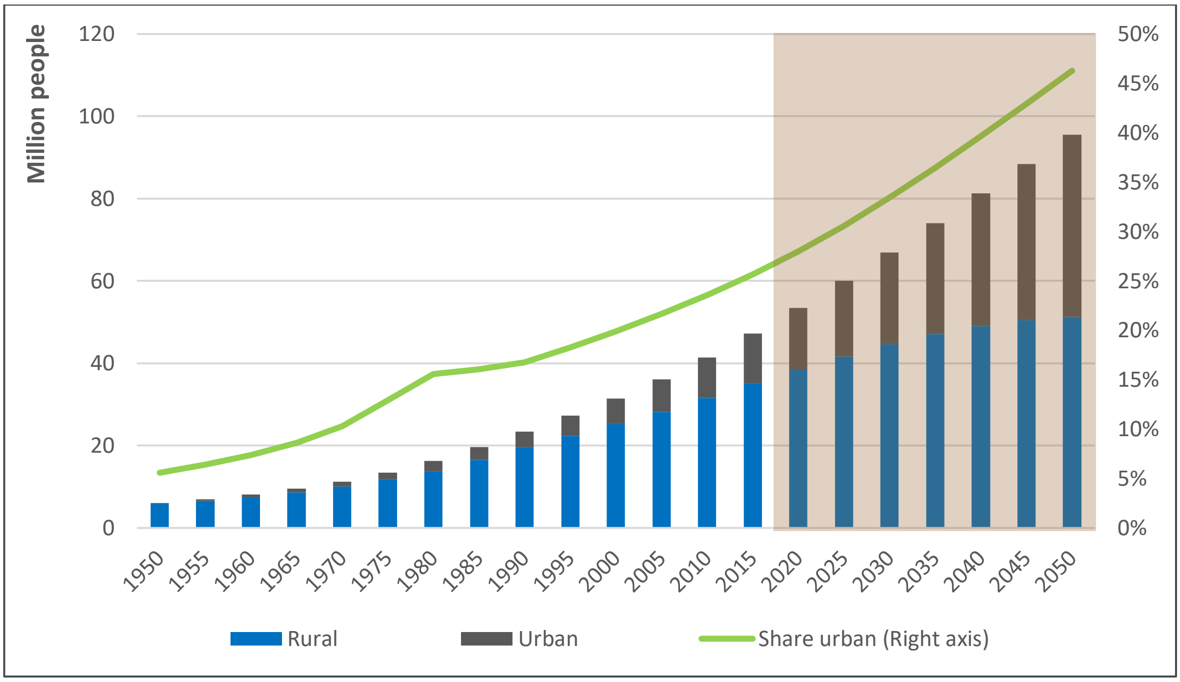

Figure 5: Projections of population growth and urbanisation in Kenya
Source: United Nations Department of Economic and Social Affairs (2018)

The main driver behind the growth in Kenya's agricultural sector has been the higher value horticultural crops such as cut flowers, and associated export earnings. Tea is the most important export crop. Trade in agricultural products is shown in Figure 6. For key food commodities such as maize and wheat Kenya remains a net importer. Maize imports are usually sourced within the region, mostly from Uganda and Tanzania. Wheat imports are not usually sourced from Africa but instead come from the world market, in particular from the Black Sea region. As explained above, these differences are important in the representation of maize and wheat markets in the model. It would be expected that wheat prices in the country would more closely follow those on world markets given the relative importance of imports and the source of them. These difference between the markets are the reason why the PE model within the ReNAPRI system for Kenya is closed differently for wheat and maize. Kenya is not as land abundant as its area would suggest (Chamberlain *et al.* 2014). Most of the productive regions are located in the south and south west of the country. The availability of appropriate land is an important consideration when interpreting the outcomes of the model.

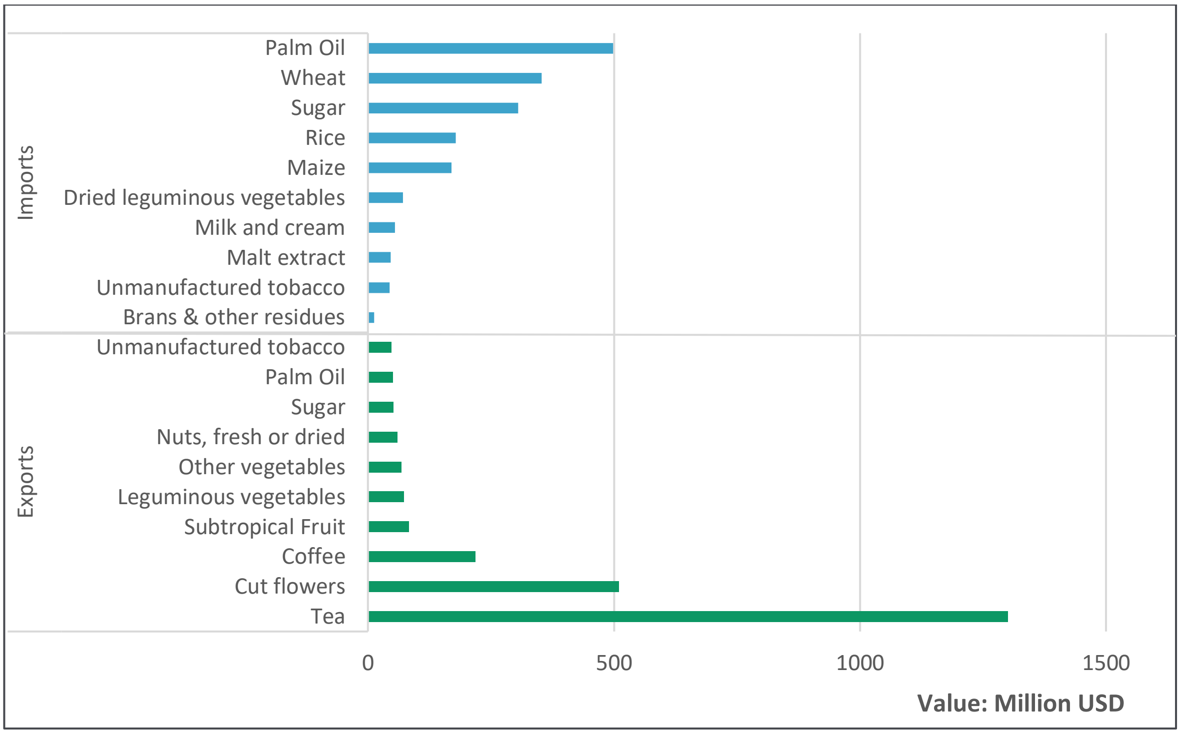

Figure 6: Major Kenyan imports and exports of agricultural products

Note: average from 2015 to 2017. Source: International Trade Council ([ITC] 2018)

4. Scenarios and results

The representation of trade in the CGE and PE models is significantly different. The CGE model differentiates between the African region and other countries. Products from the different regions are modelled as imperfect substitutes by using a two-level nested Armington specification. The PE model, however, uses a more spatial approach, separating regions by barriers to trade, such as transport costs and tariffs, and allowing prices in those different regions to evolve separately where these barriers restrict trade. The advantage of this approach is that, under the appropriate conditions, there can be significant trade flows where there were none before. An Armington approach usually cannot generate large trade flows between partners where base trade flows are low (Sanjuán López & Resano Ezcaray 2015). The expected effects of a trade liberalisation scenario in the CGE model are shown in Figure 7. To simulate regional market liberalisation, we run two scenarios eliminating import tariffs between Kenya and other African countries. Projections for the macroeconomic variables that are normally exogenous in the PE model are provided by the CGE model, which calculates them endogenously, and they are then included in the simulations of the PE model. Detailed results of the CGE model are presented in Table 2 and of the PE model are included in Appendix 2.[5]

[5] The full set of results is available from the authors upon request, especially the trade results, which have been omitted as they are very small given the low levels of tariffs initially in place.

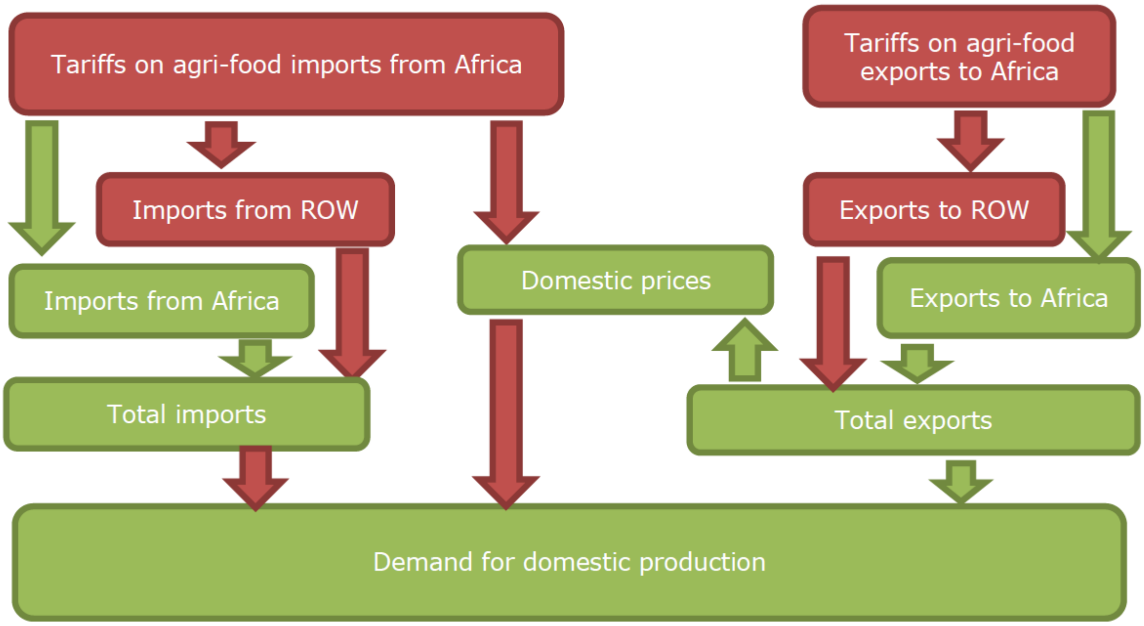

Figure 7: Main channels of expected impact of trade liberalisation
Note: The green boxes/arrows represent an increase/positive effect and the red boxes/arrows represent a decrease/negative effect. Source: Boulanger *et al.* (2018)

Changes to real GDP, GDP per capita and exchange rate from the trade liberalisation scenario of the CGE model are included in the PE analysis by adjusting the baseline assumptions with the same percentage change in the scenario relative to the baseline generated in the CGE analysis. The results of the CGE show a small reduction in income, as liberalisation has a negative effect in non-agricultural sectors and the Kenyan shilling is projected to strengthen (Table 2).

Table 2: CGE results under trade liberalisation as exogeneous input to PE model

	Real GDP per capita	Exchange rate per U.S.$
2020	-0.12	-0.54
2021	-0.11	-0.53
2022	-0.10	-0.42
2023	-0.08	-0.42
2024	-0.07	-0.31
2025	-0.07	-0.31
2026	-0.06	-0.31

Two scenarios are illustrated in the PE model. In the first of these scenarios, tariff reductions for the region are introduced as closely as possible to mimic the changes in the CGE model. For this purpose, tariffs faced by other modelled African countries[6] are reduced to 1.8%, i.e. the average tariffs faced by the African countries with which Kenya has a trade agreement (as imposed in the CGE analysis). For most countries modelled in the ReNAPRI PE model, baseline tariffs amount to only 2.8% due to existing trade agreements. For countries that do not currently have trade agreements (South Africa, Mozambique, and the rest of the world), tariffs are retained at the baseline level of 50%. Wheat tariffs are also retained at the baseline level of 10% because most wheat is imported from outside Africa. Running an identical scenario to the CGE analysis is not possible given the data, and the structure of the two models is different. Thus, the PE analysis includes a second scenario in which a reduction is also made to the maize tariff faced by South Africa and Mozambique – bringing it in line with the

[6] Besides Kenya, countries included explicitly in the ReNAPRI PE model are the Democratic Republic of Congo, Malawi, Mozambique, South Africa, Tanzania, Uganda, Zambia and Zimbabwe. Others are part of a rest of the world (ROW) aggregate.

1.8% faced by other African countries in the first trade scenario. Furthermore, the second trade scenario also incorporates a reduction in the wheat tariff that is levied by Kenya on countries outside of Africa to 3.4% (as imposed on African countries in the CGE analysis). Table 3 summarises shocks introduced in both models.

Table 3: Shocks in baseline and scenarios by modelling approach

CGE baseline
- Historical GDP growth until 2020, then 5% growth until the end of simulation period - Population growth from UN Population Prospects 2019
CGE scenario
- Twenty percent reduction in wheat (from 2.2% to 1.8%) and maize (from 4.2% to 3.4%) tariff rates
PE scenario 1
- Shocks to GDP, GDP per capita and exchange rate with CGE results - Maize tariff rates faced by other modelled African countries reduced to 1.8% for countries with a trade agreement with Kenya - Wheat tariff rates kept constant
PE scenario 2
- All shocks from the CGE, as in scenario 1 - Maize tariff rates for South Africa and Mozambique reduced to 1.8% to match CGE tariff rates - Wheat tariff rate imposed on non-African countries reduced to 3.4% to match CGE tariff rates

The results of the trade liberalisation scenarios reflect the fact that baseline tariff protection is small. Nonetheless, the combination of reducing regional tariffs on maize from 2.8% to 1.8%, and the concomitant strengthening of the exchange rate simulated in the CGE analysis, results in a reduction in the price of imported, and consequently also domestically produced, products for both maize and wheat. Over the simulation period, the average decline in maize prices from baseline levels is only 0.1%, whereas wheat prices decline by 0.5% on average. In the case of wheat, there are no changes to the tariff in the first trade liberalisation scenario, but the strengthening of the currency affects both the price of wheat directly, and reduces the cost of imported inputs.

Both area and yield for maize and wheat decline marginally. In the case of maize, the reduction in price is insufficient to offset lower income levels, hence food consumption declines by an average of 0.02% over the simulation period. However, in the wheat market, the slightly stronger price reduction is sufficient to offset the income effect, and wheat consumption rises by an average of 0.04% relative to baseline levels over the simulation period. Though still small, the most significant impact is evident in import volumes, which increase by an average of 2.2% for maize and 0.1% for wheat. In terms of volumes, this implies an increase of 8.9 thousand tonnes in maize imports by 2026 (an equivalent of 0.2% of food consumption). In terms of wheat, imports increase by 1.1 thousand tonnes by 2026, which is the equivalent of merely 0.05% of consumption (Figure 8).

Figure 8: Changes in imports under each trade liberalisation scenario

While the influences of the first trade liberalisation scenario are small, the results make sense, given the slight change in protection rates. In the second trade liberalisation scenario, the effects are increased by the fact that the maize tariff rates faced by South Africa and Mozambique in the Kenyan market are also reduced to 1.8%, while the tariff on total wheat imports is reduced to 3.1%. In the maize market, the price effect increases only very marginally, because the cost of transportation continues to inhibit large trade volumes from South Africa to Kenya. In the case of wheat, the average reduction in price over the simulation period increases to 3.1%, which is sufficient to reduce production by 2.8% on average relative to the baseline. At the same time, wheat consumption increases by an average of 0.8% over the simulation period, to give a net effect of increasing imports by an average of 1.1%. This implies that, by 2026, wheat imports increase by 25 thousand tonnes. Whilst more significant than in the first trade liberalisation scenario, this corresponds only to about 1% of total projected wheat consumption by 2026.

5. Concluding remarks

Kenya is actively involved in a process of trade liberalisation – at the regional level, with the deepening of the EAC and COMESA, and at the continental level, with the establishment of the AfCFTA. The latter is one of the key priorities of Agenda 2063 and a major step towards African continental economic integration. In May 2018, Kenya, together with Ghana, was the first nation to ratify the AfCFTA agreement. Kenya clearly adopts a strategy of market opening beyond regional partners, i.e. countries that are not members of the EAC and COMESA.

Given the characteristics of both the supply and demand sides, this paper investigates the effects on maize and wheat markets of further trade liberalisation. To do so, the methodology adopted links a PE and a CGE modelling framework. The spatial approach of the former, i.e., the ReNAPRI framework, contrasts with the Armington approach of the latter, and the different specifications are likely to result in different results. The more ad hoc approach of the PE model allows market and regional characteristics to be captured, but at a significant cost in terms of data collection and maintenance. In particular, trading arrangements and logistical costs can differ significantly between different trading routes. This is critical, and trading arrangements will play a critical role in the influence of any policy on the sector.

Special attention should be paid to the modelling of non-tariff measures (NTMs), which can be considered as any policy measure that affects trade other than ordinary tariffs. The PE model (in this case through the spatial approach) can allow a more realistic representation of trading arrangements, and this indeed is a motivator for some of the studies referred to in this paper that attempt to link the CGE and PE approaches. The CGE approach has the advantage of a more rigorous theoretical underpinning, with lower data costs (per commodity).

The link between the models adopted in this paper includes the use of output from one model as an input for the other model. Despite being technically simple, this link allows the harnessing of strengths from both approaches, providing a more comprehensive analysis. In particular, it makes it possible to include, within the PE model, input coming from a structural model that would otherwise be exogenous, thereby improving the consistency and transparency of the analysis. The example of Kenya and changes in policy in the maize and wheat sectors shows the advantage of such an approach. The importance of agriculture to the economy as a whole means that feedback from other sectors is likely to be an important driver of results. Economy-wide liberalisation scenarios might result in a reallocation of resources driven by an underlying comparative advantage that is not captured by sectoral models. In this case, the complexities of the sectors are also an important consideration for policymakers, with within-sector commodity-specific characteristics driving results. The paper illustrates an important trade-off, however, in that, as the models' content diverges, so does the ability to simulate them consistently.

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Appendix 1: Details of the ReNAPRI partial equilibrium model used

The ReNAPRI regional modelling system comprises a set of country-level, partial equilibrium models of the agricultural sector for various countries in central, eastern and southern Africa. The models are all based on a system of equations representing individual components of supply and demand in each sector, designed to incorporate the major economic, biological and policy relationships within these markets (a description and practical applications of the modelling approach can be found in Meyers et al. (2010). The individual models use econometric estimation where possible, but consistent time-series data often are not available. Where this is the case, the equations are calibrated using the available data and behavioural parameters from other studies, either from the country concerned or, where that is not possible, from similar countries in the region.

The partial equilibrium structure implies that the models take macro-economic projections, world market prices and policy assumptions as exogenous. Macro-economic views are based on those published in the latest World Economic Outlook by the International Monetary Fund, complemented by in-country information. World prices are sourced from global modelling systems, such as the Food and Agricultural Policy Research Institute (FAPRI) at the University of Missouri. Policy assumptions are based on information from in-country analysts.

Kenya maize model structure

Within the demand-and-supply block, the Kenyan maize model follows a fairly conventional specification, with supply responses based on returns from maize and other competing crops, and demand driven by income and prices. The trade equations are specified in accordance with Davids *et al*. (2018) in order to allow for regional trade and pricing dynamics to be captured more efficiently, in particular in terms of how they related to white maize. Prices are determined as an equilibrium solution, where total supply is equal to total demand. Specific equations that comprise the supply, demand and trade blocks are detailed below.

Maize supply block

Input identities

Maize production cost index

$$KEN\_MZ\_CI = 0.22FERT + 0.13FUEL + 0.1SEED + 0.55INFL$$

Variable name	Description
Intercept	Intercept
KEN_MZ_CI	Kenya maize production cost index
$FERT$	Kenya fertiliser price index
$FUEL$	Kenya fuel price index
$SEED$	Kenya seed price index
$INFL$	Kenya GDP deflator index

Maize returns

$$KEN\_MZ\_RET = \frac{KEN\_MZ\_PP \; x \; KEN\_MZ\_YLD}{KEN\_MZ\_CI}$$

Variable name	Description
Intercept	Intercept
KEN_MZ_RET	Kenya maize returns
KEN_MZ_PP	Kenya maize producer price
KEN_MZ_YLD	Kenya national average maize yield
KEN_MZ_CI	Kenya maize cost index

Supply equations

Maize area harvested

$$KEN\_MZ\_AH = \alpha_1 + \beta_1 KEN\_MZ\_AH\,(-1) + \beta_2 KEN\_MZ\_RET + \beta_3 KEN\_MZ\_PR..CE + \beta_4 Trend + \varepsilon$$

Variable Name	Description	Coefficient	Average elasticity
Intercept	Intercept	857.00	
KEN_MZ_AH (-1)	Maize area, lagged one year	0.20	
KEN_MZ_RET	Three-year moving average of maize returns	1.53	0.15
KEN_MZ_PR..CE	Maize price / average other cereal prices	97.49	0.05
Trend	Linear trend	10.00	

Maize yield

$$KEN\_MZ\_YLD = \alpha_1 + \beta_1 KEN\_MZ\_AH + \beta_2 KEN\_MZ\_RET + \beta_3 Trend + \varepsilon$$

Variable name	Description	Coefficient	Average elasticity
Intercept	Intercept	1.49	
KEN_MZ_AH	Maize area, current year	-0.001	-1.13
KEN_MZ_RET	Three-year moving average of maize returns	0.01	1.23
Trend	Linear trend	0.00	

Maize production

$$KEN\_MZ\_QP = KEN\_MZ\_AH \; x \; KEN\_MZ\_YLD$$

Variable name	Description
Intercept	Intercept
KEN_MZ_QP	Maize production
KEN_MZ_AH	Maize area harvested
KEN_MZ_YLD	National average maize yield

Demand equations

Food consumption

$$KEN\_MZ\_PC = \alpha_1 + \beta_1 KEN\_MZ\_PP..GDPDEF + \beta_2 KEN\_ME\_GDPPC + \varepsilon$$

Variable name	Description	Coefficient	Average elasticity
Intercept	Intercept	90.00	
KEN_MZ_PP..GDPDEF	Maize price, deflated by GDP deflator index	-0.17	-0.30
KEN_ME_GDPPC	Real GDP per capita	0.0004	0.03

Feed consumption

$$KEN\_MZ\_FE = \alpha_1 + \beta_1 KEN\_LS\_FEGR + \beta_2 KEN\_MZ\_PP..WT + \beta_3 KEN\_MZ\_PP..BA + \beta_4 Trend + \varepsilon$$

Variable name	Description	Coefficient	Average elasticity
Intercept	Intercept	-130.00	
KEN_LS_FEGR	Calculated grain feed requirement	0.08	1
KEN_MZ_PP..WT	Maize price / wheat price	-16.15	-0.05
KEN_MZ_PP..BA	Maize price / barley price	-7.16	-0.05
Trend	Linear trend	15.00	

Animal production and feed requirements

Livestock production

KEN_MK_QP = Historical growth trend of 20.68
KEN_BV_QP = Historical growth trend of 0.5
KEN_PK_QP = Historical growth trend of 1
KEN_PT_QP = Historical growth trend of 2

Variable name	Description
Intercept	Intercept
KEN_MK_QP	Kenya milk production
KEN_BV_QP	Kenya beef production
KEN_PK_QP	Kenya pork production
KEN_PT_QP	Kenya poultry production

Feed requirement assumptions

Product	Output-to-feed conversion ratio	Grain share of feed requirement	Protein share of feed requirement
Milk	0.3	98%	2%
Beef	4.0	99%	1%
Pork	4.0	90%	10%
Poultry	3.0	80%	20%

Feed consumption

$$KE\_FE\_QC = 0.3KE\_MK\_QP + 4KE\_BV\_QP + 4KE\_PK\_QP + 3KE\_PT\_QP$$

Maize ending stock

$$KEN\_MZ\_ES = \alpha_1 + \beta_1 KEN\_MZ\_ES\,(-1) + \beta_2 KEN\_MZ\_PP..GDPDEF + \beta_3 KEN\_MZ\_QP + \varepsilon$$

Variable name	Description	Coefficient	Average elasticity
Intercept	Intercept	100.00	
KEN_MZ_ES (-1)	Maize ending stock, lagged one year	0.30	
KEN_MZ_PP..GDPDEF	Maize price, deflated by GDP deflator index	-1.88	-0.60
KEN_MZ_QP	Kenya maize production	0.03	0.20

Trade equations

Kenya exports to each partner market

KEN_MZ_EX..PARTNER

$$= \begin{cases} 0 \; if \; PARTNER\_MZ\_PP + m_{ij} < \text{KEN\_MZ\_PP} + T_{ij}) \times (1 + TR_{ij}) \\ \beta_1(PARTNER\_MZ\_PP - (\text{KEN\_MZ\_PP} + T_{ij}) \times (1 + TR_{ij}) + m_{ij}) \; if \; PARTNER\_MZ\_PP + m_{ij} > (\text{KEN\_MZ\_PP} + T_{ij}) \times (1 + TR_{ij}) \\ \beta_2(PARTNER\_MZ\_PP - (\text{KEN\_MZ\_PP} + T_{ij}) \times (1 + TR_{ij}) - k_{ij}) \; if \; PARTNER\_MZ\_PP - k_{ij} > (\text{KEN\_MZ\_PP} + T_{ij}) \times (1 + TR_{ij}) \end{cases}$$

Variable name	**Description**
PARTNER_MZ_PP	Maize price in market of destination
KEN_MZ_PP	Kenyan maize price: Eldoret
T_{ij}	Estimated cost of trade between Kenya and PARTNER
TR_{ij}	Tariff rate applied by PARTNER markets on maize imported from Kenya

Parameters

Exporter	**Importer**	m_{ij}	k_{ij}	β_1	β_2
Kenya: Eldoret	Malawi: Lilongwe	100	0	0.50	5.00
Kenya: Eldoret	Mozambique: Maputo	20	10	0.25	2.50
Kenya: Eldoret	South Africa: Randfontein	20	10	0.25	2.50
Kenya: Eldoret	Tanzania: Arusha	70	0	0.20	2.00
Kenya: Eldoret	Uganda: Kampala	10	10	0.25	1.25
Kenya: Eldoret	Zambia: Lusaka	20	10	0.25	2.50
Kenya: Eldoret	Zimbabwe: Harare	20	10	0.25	2.50
Kenya: Eldoret	Other	100	-50	0.25	2.50

Kenya imports

Imports are set equal to exports from relevant trade partners and thus the only import equation is from the rest of the world, specified in the same way as the export equations.

Assumptions on import parameters

Importer	m_{ij}	k_{ij}	l_{ij}	β_1	β_2	β_3
Kenya	50	-20	NA	0.80	6.40	NA

Structure of Kenya wheat model

The structure of the wheat model is more conventional, given that Kenya is a consistent net importer of wheat and that the majority of such imports originate from outside the Eastern and Southern Africa region – implying that Kenya trades consistently with the global market. Consequently, prices are determined as a function of world prices, adjusted for exchange rate dynamics and tariffs, in combination with a self-sufficiency ratio, which captures some supply and demand dynamics in the price solution. Model closure is achieved through an import identity. The domestic supply-and-demand specifications are similar to those of maize, and are presented below.

Wheat supply block

Wheat area

$$KEN\_WH\_AH = \alpha_1 + \beta_1 KEN\_WH\_AH\,(-1) + \beta_2 KEN\_WH\_PP..GDPDEF + \beta_3 KEN\_SG\_PP..GDPDEF + \beta_3 Rainfall + \beta_4 Liberalisation + \varepsilon$$

Variable name	Description	Coefficient	Average elasticity
Intercept	Intercept	115.74	
KEN_WH_AH (-1)	Wheat area, lagged one year	0.26	
KEN_WH_PP..GDPDEF (-1)	Real wheat price, lagged one year	0.0015	0.22
KEN_SG_PP..GDPDEF (-1)	Real sorghum price, lagged one year	-0.0001	0.00
Rainfall	Rainfall variable	-0.0024	
Liberalisation	Liberalisation dummy	-13.29	

Wheat yield

$$KEN\_WH\_YLD = \alpha_1 + \beta_1 KEN\_WH\_PP..GDPDEF + \beta_2 Trend + \varepsilon$$

Variable name	Description	Coefficient	Average elasticity
Intercept	Intercept	1.49	
KEN_WH_PP..GDPDEF	Wheat price, deflated by GDP deflator index	0.0008	0.68
Trend	Linear trend	1.52	

Wheat production

KEN_WH_QP = KEN_WH_AH*KEN_WH_YLD

Variable name	Description
KEN_WH_QP	Wheat production
KEN_WH_AH	Wheat area harvested
KEN_WH_YLD	National average wheat yield

Wheat demand block

Wheat consumption per capita

$$KEN\_WH\_PC = \alpha_1 + \beta_1 KEN\_WH\_PP..GDPDEF + \beta_2 KEN\_SG\_PP..GDPDEF + \beta_3 KEN\_ME\_GDPPC + \beta_3 KEN\_ME\_GDPPC + \beta_4 SHIFT2009 + \varepsilon$$

Variable name	Description	Coefficient	Average elasticity
Intercept	Intercept	14.24	
KEN_WH_PP..GDPDEF	Wheat price, deflated by GDP deflator index	-0.00021	-0.25
KEN_SG_PP..GDPDEF	Sorghum price, deflated by GDP deflator index	0.00006	0.003
KEN_ME_GDPPC	Real GDP per capita	0.15	0.34
SHIFT2009	Shift dummy = 1 after 2009	10.28	

Domestic wheat consumption

$KEN\_WH\_QC = KEN\_WH\_PC$ x KEN_ME_POP

Variable name	Description
KEN_WH_QC	Wheat consumption
KEN_WH_PC	Wheat consumption per capita
KEN_ME_POP	Population of Kenya

Wheat ending stock

$$KEN\_WH\_ES = \alpha_1 + \beta_1 KEN\_WH\_ES\,(-1) + \beta_2 KEN\_WH\_PP..GDPDEF + \beta_3 KEN\_WH\_QP + \varepsilon$$

Variable name	Description	Coefficient	Average elasticity
Intercept	Intercept	-2.88	
KEN_WH_ES (-1)	Wheat ending stock, lagged one year	-.38	
KEN_WH_PP..GDPDEF	Wheat price, deflated by GDP deflator index	-0.00095	-0.11
KEN_WH_QP	Kenya wheat production	0.73	1.34

Wheat price

$$KEN\_WH\_PP = \alpha_1 + \beta_1 KEN\_WH\_WDPKEN + \beta_2 KEN\_WH\_SUF + \varepsilon$$

Variable name	Description	Coefficient	Average elasticity
Intercept	Intercept	5 677	
KEN_WH_WDPKEN	World wheat price*KSH$ exchange rate + tariff	0.85	0.83
KEN_WH_SUF	Wheat consumption / wheat production ratio	583	0.4

Net wheat imports (closing)

Domestic wheat consumption

KEN_WH_IM = KEN_WH_QP + KEN_WT_ES (-1) – KEN_WT_QC – KEN_WT_ES

Variable name	Description
KEN_WH_IM	Kenyan wheat imports
KEN_WT_QP	Kenyan wheat production
KEN_WH_ES (-1)	Kenya wheat ending stocks, lagged by one year
KEN_WT_QC	Kenyan wheat consumption
KEN_WT_ES	Kenya wheat ending stocks

Data description

Data series	Source	Period of historic series
Maize area harvested	Kenya Ministry of Agriculture, Livestock and Fisheries, and validation by ReNAPRI	2001–2017
Maize yield	Kenya Ministry of Agriculture, Livestock and Fisheries, and validation by ReNAPRI	2001–2017
Maize production	Kenya Ministry of Agriculture, Livestock and Fisheries, and validation by ReNAPRI	2001–2017
Maize food consumption	Balancing calculation	2001–2017
Maize feed use	FAO	2001–2017
Maize ending stocks	Kenya Ministry of Agriculture, Livestock and Fisheries, and validation by ReNAPRI	2001–2017
Maize trade	ITC Trademap & FEWSNET informal trade	2001–2017
Maize prices	FAO GIEWS food price tool	2001–2017
Livestock production	FAO	2001–2017
Wheat area harvested	Kenya Ministry of Agriculture, Livestock and Fisheries, and validation by ReNAPRI	2001–2017
Wheat yield	Kenya Ministry of Agriculture, Livestock and Fisheries, and validation by ReNAPRI	2001–2017
Wheat production	Kenya Ministry of Agriculture, Livestock and Fisheries, and validation by ReNAPRI	2001–2017
Wheat consumption	Balancing calculation	2001–2017
Wheat ending stock	Wheat Atlas	2001–2017
Wheat trade	ITC Trademap	2001–2017
Wheat prices	Kenya Ministry of Agriculture, Livestock and Fisheries	2001–2017

Fertiliser price index	International Index sourced from FAPRI, converted into domestic currency	2001–2017
Fuel price index	International Index sourced from FAPRI, converted into domestic currency	2001–2017
Macroeconomic variables	IMF World Economic Outlook and UN World Population Prospects	2001–2017

Appendix 2: Modelling results

Baseline

		2020	2021	2022	2023	2024	2025	2026
Macro								
Real GDP per Capita	2010 KES/hd	105468	109323	113341	117039	120859	124803	128876
GDP deflator	% change previous	5.2	5.0	5.0	5.0	5.0	5.0	5.0
Exchange rate per U.S.$		110.6	113.8	116.6	119.4	122.3	125.3	128.4
Population	Million head	50.7	52.1	53.5	55	56.4	58	59.5
Maize								
Area	000 ha	2111	2144	2164	2179	2193	2208	2225
Yield	tonnes/ha	1.85	1.87	1.90	1.92	1.95	1.98	2.00
Production	000 tonnes	3899	4017	4110	4195	4279	4366	4457
Imports	000 tonnes	467	492	524	562	605	649	699
Exports	000 tonnes	6	6	6	6	6	6	7
Consumption	000 tonnes	4370	4499	4623	4746	4873	5004	5143
Food	000 tonnes	3718	3831	3939	4046	4157	4271	4395
Feed	000 tonnes	452	468	484	500	516	532	549
Ending Stock	000 tonnes	517	521	526	532	537	543	549
Kenyan Price	KES/tonne	33588	34424	35641	37031	38446	39951	41265
Wheat								
Area	000 ha	141	141	141	141	140	140	139
Yield	tonnes/ha	1.51	1.52	1.54	1.55	1.57	1.58	1.58
Production	000 tonnes	213	215	217	218	220	221	220
Imports	000 tonnes	1740	1845	1913	1996	2080	2169	2251
Exports	000 tonnes	10	10	10	10	10	10	11
Consumption	000 tonnes	1961	2041	2122	2203	2289	2379	2461
Food	000 tonnes	1799	1876	1958	2040	2125	2215	2297
Feed	000 tonnes	115	115	115	115	115	115	116
Ending Stocks	000 tonnes	102	111	109	111	112	113	112
Kenyan Price	KES/tonne	43634	45591	47094	48447	49914	51120	52258

Liberalisation Scenario 1

		2020	2021	2022	2023	2024	2025	2026
Macro								
Real GDP per Capita	2010 KES/hd	105337	109204	113232	116940	120768	124721	128801
GDP deflator	% change previous	5.2	5.0	5.0	5.0	5.0	5.0	5.0
Exchange rate per U.S.$		110.0	113.2	116.1	118.9	121.9	124.9	128.0
Population	Million head	50.7	52.1	53.5	55.0	56.4	58.0	59.5
Maize								
Area	000 ha	2110	2143	2163	2178	2192	2208	2225
Yield	tonnes/ha	1.84	1.87	1.89	1.92	1.95	1.97	2.00
Production	000 tonnes	3883	4001	4096	4182	4268	4356	4448
Imports	000 tonnes	482	506	537	574	615	658	708
Exports	000 tonnes	6	6	6	6	6	6	7
Consumption	000 tonnes	4368	4498	4621	4744	4872	5003	5142
Food	000 tonnes	3717	3830	3937	4044	4156	4271	4394
Feed	000 tonnes	452	468	484	500	516	532	549
Ending Stock	000 tonnes	516	520	526	531	537	543	549
Kenyan Price	KES/tonne	33592	34415	35636	37017	38441	39938	41247
Wheat								
Area	000 ha	141	141	141	140	140	140	139
Yield	tonnes/ha	1.50	1.52	1.54	1.55	1.57	1.58	1.58
Production	000 tonnes	212	214	216	218	219	221	220
Imports	000 tonnes	1741	1846	1914	1998	2081	2170	2252
Exports	000 tonnes	10	10	10	10	10	10	11
Consumption	000 tonnes	1962	2042	2123	2204	2290	2379	2462
Food	000 tonnes	1800	1877	1958	2040	2125	2215	2297
Feed	000 tonnes	115	115	115	115	115	115	116
Ending Stocks	000 tonnes	101	110	109	111	111	112	112
Kenyan Price	KES/tonne	43480	45430	46960	48309	49808	51011	52147

Absolute change from baseline

		2020	2021	2022	2023	2024	2025	2026
Macro								
Real GDP per Capita	2010 KES/hd	-130.96	-119.37	-108.98	-99.23	-90.55	-82.35	-75.22
GDP deflator	% change previous	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exchange rate per U.S.$		-0.59	-0.61	-0.49	-0.50	-0.39	-0.39	-0.40
Population	Million head	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Maize								
Area	000 ha	-0.64	-0.85	-0.87	-0.80	-0.73	-0.65	-0.59
Yield	tonnes/ha	-0.01	-0.01	-0.01	-0.01	0.00	0.00	0.00
Production	000 tonnes	-16.49	-16.01	-13.95	-13.03	-11.12	-10.37	-9.84
Imports	000 tonnes	14.58	14.57	12.68	11.91	10.06	9.41	8.89
Exports	000 tonnes	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Consumption	000 tonnes	-1.58	-1.41	-1.30	-1.19	-1.09	-1.02	-1.00
Food	000 tonnes	-1.46	-1.29	-1.21	-1.10	-1.02	-0.95	-0.94
Feed	000 tonnes	-0.12	-0.12	-0.09	-0.09	-0.07	-0.07	-0.06
Ending Stock	000 tonnes	-0.50	-0.53	-0.50	-0.44	-0.40	-0.34	-0.30
Kenyan Price	KES/tonne	3.63	-8.34	-4.36	-13.38	-5.88	-12.99	-17.80
Wheat								
Area	000 ha	-0.12	-0.11	-0.10	-0.09	-0.08	-0.06	-0.06
Yield	tonnes/ha	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Production	000 tonnes	-0.75	-0.74	-0.62	-0.58	-0.45	-0.42	-0.40
Imports	000 tonnes	1.42	1.57	1.32	1.35	1.04	1.03	1.14
Exports	000 tonnes	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Consumption	000 tonnes	0.64	0.83	0.63	0.77	0.50	0.62	0.73
Food	000 tonnes	0.64	0.83	0.63	0.77	0.50	0.62	0.73
Feed	000 tonnes	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ending Stocks	000 tonnes	-0.36	-0.36	-0.28	-0.28	-0.20	-0.21	-0.19
Kenyan Price	KES/tonne	-153.48	-161.45	-133.45	-137.69	-106.23	-109.08	-110.98

Percentage change from baseline	2020	2021	2022	2023	2024	2025	2026
Macro							
Real GDP per Capita	-0.12%	-0.11%	-0.10%	-0.08%	-0.07%	-0.07%	-0.06%
GDP deflator	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Exchange rate per U.S.$	-0.54%	-0.53%	-0.42%	-0.42%	-0.31%	-0.31%	-0.31%
Population	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Maize							
Area	-0.03%	-0.04%	-0.04%	-0.04%	-0.03%	-0.03%	-0.03%
Yield	-0.39%	-0.36%	-0.30%	-0.27%	-0.23%	-0.21%	-0.19%
Production	-0.42%	-0.40%	-0.34%	-0.31%	-0.26%	-0.24%	-0.22%
Imports	3.12%	2.96%	2.42%	2.12%	1.66%	1.45%	1.27%
Exports	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Consumption	-0.04%	-0.03%	-0.03%	-0.03%	-0.02%	-0.02%	-0.02%
Food	-0.04%	-0.03%	-0.03%	-0.03%	-0.02%	-0.02%	-0.02%
Feed	-0.03%	-0.02%	-0.02%	-0.02%	-0.01%	-0.01%	-0.01%
Ending Stock	-0.10%	-0.10%	-0.10%	-0.08%	-0.07%	-0.06%	-0.05%
Kenyan Price	0.01%	-0.02%	-0.01%	-0.04%	-0.02%	-0.03%	-0.04%
Wheat							
Area	-0.08%	-0.08%	-0.07%	-0.06%	-0.06%	-0.05%	-0.04%
Yield	-0.27%	-0.27%	-0.21%	-0.20%	-0.15%	-0.14%	-0.14%
Production	-0.35%	-0.34%	-0.28%	-0.27%	-0.21%	-0.19%	-0.18%
Imports	0.08%	0.09%	0.07%	0.07%	0.05%	0.05%	0.05%
Exports	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Consumption	0.03%	0.04%	0.03%	0.04%	0.02%	0.03%	0.03%
Food	0.04%	0.04%	0.03%	0.04%	0.02%	0.03%	0.03%
Feed	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Ending Stocks	-0.35%	-0.32%	-0.25%	-0.25%	-0.18%	-0.18%	-0.17%
Kenyan Price	-0.35%	-0.35%	-0.28%	-0.28%	-0.21%	-0.21%	-0.21%

Trade Liberalisation Scenario 2

		2020	2021	2022	2023	2024	2025	2026
Macro								
Real GDP per Capita	2010 KES/hd	105337	109204	113232	116940	120768	124721	128801
GDP deflator	% change previous	5.2	5.0	5.0	5.0	5.0	5.0	5.0
Exchange rate per U.S.$		110.0	113.2	116.1	118.9	121.9	124.9	128.0
Population	Million head	50.7	52.1	53.5	55.0	56.4	58.0	59.5
Maize								
Area	000 ha	2111	2144	2164	2179	2193	2208	2225
Yield	tonnes/ha	1.84	1.87	1.89	1.92	1.95	1.97	2.00
Production	000 tonnes	3882	4000	4095	4181	4267	4355	4447
Imports	000 tonnes	482	507	537	575	616	659	709
Exports	000 tonnes	6	6	6	6	6	6	7
Consumption	000 tonnes	4368	4497	4621	4744	4872	5003	5142
Food	000 tonnes	3716	3829	3937	4044	4156	4270	4394
Feed	000 tonnes	452	468	484	500	516	532	549
Ending Stock	000 tonnes	516	520	526	531	537	542	549
Kenyan Price	KES/tonne	33599	34424	35646	37027	38450	39948	41257
Wheat								
Area	000 ha	140	140	140	140	139	139	138
Yield	tonnes/ha	1.47	1.49	1.50	1.52	1.54	1.55	1.55
Production	000 tonnes	206	208	211	212	214	215	214
Imports	000 tonnes	1759	1866	1935	2019	2103	2193	2276
Exports	000 tonnes	10	10	10	10	10	10	11
Consumption	000 tonnes	1975	2056	2138	2220	2306	2397	2481
Food	000 tonnes	1813	1891	1974	2056	2142	2233	2316
Feed	000 tonnes	115	115	115	115	115	115	116
Ending Stocks	000 tonnes	98	108	106	108	109	110	109
Kenyan Price	KES/tonne	42256	44137	45621	46935	48393	49560	50670

Absolute change from baseline

		2020	2021	2022	2023	2024	2025	2026
Macro								
Real GDP per Capita	2010 KES/hd	-130.96	-119.37	-108.98	-99.23	-90.55	-82.35	-75.22
GDP deflator	% change previous	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exchange rate per U.S.$		-0.59	-0.61	-0.49	-0.50	-0.39	-0.39	-0.40
Population	Million head	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Maize								
Area	000 ha	-0.12	-0.30	-0.33	-0.24	-0.16	-0.07	-0.01
Yield	tonnes/ha	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.00
Production	000 tonnes	-17.22	-16.94	-14.92	-14.01	-12.18	-11.49	-10.99
Imports	000 tonnes	15.12	15.28	13.44	12.69	10.93	10.33	9.83
Exports	000 tonnes	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Consumption	000 tonnes	-1.74	-1.61	-1.50	-1.39	-1.28	-1.21	-1.20
Food	000 tonnes	-1.62	-1.49	-1.40	-1.29	-1.21	-1.14	-1.13
Feed	000 tonnes	-0.13	-0.12	-0.10	-0.10	-0.08	-0.07	-0.07
Ending Stock	000 tonnes	-0.56	-0.61	-0.59	-0.53	-0.49	-0.43	-0.39
Kenyan Price	KES/tonne	10.92	0.84	5.06	-3.83	3.51	-3.04	-7.26
Wheat								
Area	000 ha	-0.89	-0.92	-0.93	-0.91	-0.89	-0.85	-0.83
Yield	tonnes/ha	-0.04	-0.04	-0.04	-0.03	-0.03	-0.03	-0.03
Production	000 tonnes	-6.49	-6.57	-6.42	-6.26	-6.03	-5.86	-5.67
Imports	000 tonnes	19.91	21.60	22.18	22.96	23.42	24.21	24.97
Exports	000 tonnes	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Consumption	000 tonnes	13.68	14.98	15.68	16.63	17.27	18.28	19.20
Food	000 tonnes	13.68	14.98	15.68	16.63	17.27	18.28	19.20
Feed	000 tonnes	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ending Stocks	000 tonnes	-3.20	-3.16	-3.07	-3.00	-2.87	-2.81	-2.71
Kenyan Price	KES/tonne	-1378.19	-1454.59	-1472.95	-1511.29	-1521.20	-1560.27	-1588.71

Percentage change from baseline								
		2020	2021	2022	2023	2024	2025	2026
Macro								
Real GDP per Capita	2010 KES/hd	-0.12%	-0.11%	-0.10%	-0.08%	-0.07%	-0.07%	-0.06%
GDP deflator	% change previous	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Exchange rate per U.S.$		-0.54%	-0.53%	-0.42%	-0.42%	-0.31%	-0.31%	-0.31%
Population	Million head	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Maize								
Area	000 ha	-0.01%	-0.01%	-0.02%	-0.01%	-0.01%	0.00%	0.00%
Yield	tonnes/ha	-0.44%	-0.41%	-0.35%	-0.32%	-0.28%	-0.26%	-0.25%
Production	000 tonnes	-0.44%	-0.42%	-0.36%	-0.33%	-0.28%	-0.26%	-0.25%
Imports	000 tonnes	3.24%	3.11%	2.56%	2.26%	1.81%	1.59%	1.41%
Exports	000 tonnes	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Consumption	000 tonnes	-0.04%	-0.04%	-0.03%	-0.03%	-0.03%	-0.02%	-0.02%
Food	000 tonnes	-0.04%	-0.04%	-0.04%	-0.03%	-0.03%	-0.03%	-0.03%
Feed	000 tonnes	-0.03%	-0.03%	-0.02%	-0.02%	-0.02%	-0.01%	-0.01%
Ending Stock	000 tonnes	-0.11%	-0.12%	-0.11%	-0.10%	-0.09%	-0.08%	-0.07%
Kenyan Price	KES/tonne	0.03%	0.00%	0.01%	-0.01%	0.01%	-0.01%	-0.02%
Wheat								
Area	000 ha	-0.63%	-0.65%	-0.66%	-0.65%	-0.63%	-0.61%	-0.60%
Yield	tonnes/ha	-2.44%	-2.42%	-2.31%	-2.24%	-2.12%	-2.05%	-1.99%
Production	000 tonnes	-3.06%	-3.06%	-2.96%	-2.87%	-2.74%	-2.65%	-2.58%
Imports	000 tonnes	1.14%	1.17%	1.16%	1.15%	1.13%	1.12%	1.11%
Exports	000 tonnes	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Consumption	000 tonnes	0.70%	0.73%	0.74%	0.75%	0.75%	0.77%	0.78%
Food	000 tonnes	0.76%	0.80%	0.80%	0.82%	0.81%	0.83%	0.84%
Feed	000 tonnes	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Ending Stocks	000 tonnes	-3.15%	-2.85%	-2.82%	-2.71%	-2.58%	-2.50%	-2.42%
Kenyan Price	KES/tonne	-3.16%	-3.19%	-3.13%	-3.12%	-3.05%	-3.05%	-3.04%