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The impact of production shocks on maize markets in Ethiopia: implications for regional trade and food security

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Abstract

In this article, we demonstrated the dynamic impact of a bumper harvest and drought shocks on the maize market and on the trade regime in Ethiopia. Regional market integration of Ethiopia's white maize market with the South Sudan and Kenyan maize markets was also examined using cointegration analysis. Despite the renewed conflict in South Sudan, Addis Ababa maize market is cointegrated with Juba's maize market. The simulation analysis indicated that a 20% increase in maize yield could reduce the maize price by 81%. This implies a decrease in the maize price level of 70% (110 USD/t) below the export parity price. This makes maize exports profitable and shifts the trade regime from autarky to an export parity regime. On the other hand, the effect of a drought could increase maize prices by 61% in the short run (within the year). At the current market price, the domestic maize price is wandering between the border prices and it is unprofitable to export maize. Therefore, lifting the export ban, even during normal harvest seasons, would not do any harm to the domestic maize price.

Keywords: Export bans, Maize, Price stabilization, Production shocks, Traders

Introduction

In many African countries, the majority of households spend much of their expenditure on food items.[1] As a result, high food prices present huge risks to the food security status of the region. In this instance, the question should not be whether African governments ought to intervene but, instead, how African governments could provide stability to grain prices without disrupting the domestic grain market environment. This is the challenge for many African countries that are responding with short-term stabilization interventions[2] by allowing state marketing parastatals to undertake the price stabilization job. This traditional method of price stabilization is counterintuitive by impeding private traders and could make prices even more unstable and

[1]In 2011, the share of food consumption expenditures in the total consumption basket of Ethiopian households was 48% (see Worku et al. 2015).
[2]According to Jayne (2012), most countries in eastern and southern Africa follow the same discretionary state-led interventions in stabilizing grain markets. This form of intervention is characterized by unplanned and sudden export bans, and the issuing of government tenders for imports, which will be sold at subsidized prices in domestic markets without being well publicized to other stakeholders. This was the case for Sub-Saharan African countries such as Zambia, Ethiopia, Malawi, and Kenya.

unpredictable (Minot 2014). Hence, African governments need to find effective means of managing food price risks.

African governments implemented a wide range of policy responses to cushion the impact of the 2007/2008 food crisis. The major policy responses included consumer support measures (safety net programs, reducing tariffs and domestic taxes, and releasing stocks) and trade and price control measures (export bans, price controls, and foreign exchange restrictions) (Demeke et al. 2009 and Demeke et al. 2014). However, most of these interventions were the result of panic and even worsened the situation in some African countries such as Malawi and Ethiopia (Jayne 2012). Minot (2011), in his comprehensive analysis, argued that African governments' 'fire-fighting' and ill-advised policy interventions contributed more to the food price spikes of 2008, rather than the price shocks from international market did.

Among trade policies, the major form of intervention comprises export bans. After the 2008 crisis period, Egypt, Malawi, Tanzania, Uganda, and Zimbabwe have imposed export bans. Zambia recently lifted its export ban on maize and maize products (Food and Agriculture Policy Decision Analysis Tool (FAPDA) 2017). Export bans can reduce domestic grain prices if export is profitable. However, there are diverging views on the impact of export bans on commodity market prices in Africa. Porteous (2012) and Chapoto and Jayne (2009) found no significant relationship between an export ban and domestic prices. The authors argue that in most African countries, export bans are implemented in response to soaring domestic grain prices. Unless the prices in other trading countries rise much faster, the higher domestic prices are likely to make exports unprofitable and the ban unnecessary. In contrast, Diao et al. (2013) found that the maize export ban in Tanzania reduced maize producer prices by 9 to 19%. The experiences of Malawi, Zambia and Kenya have indicated that imposing an export ban may create uncertainty in the grain market. In these countries, the government has been actively involved in large-scale maize imports in response to supply shortfalls. In some cases, this is accompanied by a ban on private grain trade. Even when the ban is lifted, the uncertainty arising from involvement of state trading enterprises in the grain market makes it difficult for traders to profitably import maize. This uncertainty in the grain market environment is expected to contribute to food price spikes (Dorosh et al. 2009 and Dorosh et al. 2016).

The Ethiopian government has imposed an export ban on maize since 2008. From a food security perspective, the ban is expected to improve domestic maize consumption. However, the export ban may also create a disincentive for production if the domestic maize price decline below the export parity price. Since maize is a major food crop in Ethiopia, any price instability in the domestic maize market is expected to have an adverse effect on other tradable and non-tradable goods (Getnet 2009; Rashid 2011). Nevertheless, the export ban may also distort maize food availability and food security in the eastern Africa region. Maize is the major staple crop consumed and traded in the region. It is the second most-traded commodity,[3] next to sesame, in the east African cross-border area. Owing to low maize yields, recurrent wars, and drought, several eastern Africa countries have relied on cross-border maize trade to fill their shortfalls.

[3]Maize commodities have constituted about 18% of the cross-border trade in the east Africa region (FEWS NET 2016).

For instance, countries such as South Sudan, Kenya, Rwanda, and Somalia rely on formal and informal cross-border trade to import maize. These regional maize demands have been mainly met by imports from Uganda and Tanzania (FEWS NET 2016). However, maize production in Tanzania and Uganda does not exceed 3.5 million metric tons and is not enough to supply the regional demand. For instance, South Sudan alone imported more than 500 thousand tons in 2013 (Dorosh et al. 2016). Furthermore, Tanzania has tightened up on maize exports to the region, depending on domestic harvest conditions.

The Ethiopian maize market has the potential to supply affordable and quality white maize to eastern Africa countries. Several initiatives for maize exports to eastern Africa maize-deficit countries are being halted by the Ethiopian export ban. The World Food Program (WFP) initiative, the Purchase from Africans for Africans (PAA) programme, planned to procure maize from Ethiopian farmers for export to the rest of the eastern Africa countries (Nogales and Fonseca 2014). However, the frequent export ban has become the main roadblock to this initiative.

In order to solve this pressing issue, the Ethiopian government has requested the agricultural advising agency, Agricultural Transformation Agency (ATA), to advice government as to whether to lift the export ban in case of good harvest seasons. This article has attempted to support the on-going policy discussions by providing evidence on the likely impact of production shocks on the white maize market in Ethiopia. Existing literature have examined the impact of production shocks on the Ethiopian agriculture at one point in time, which is inadequate to capture the effect of weather-induced shocks across time (Dercon and Krishnan 2000; Dercon 2004; Deressa and Hassan 2010; Porter 2012; Thiede 2014; Hill and Porter 2017). In this article, we simulate the dynamic impact of production shocks (a bumper harvest and drought shocks) on the maize market in Ethiopia. Additionally, we examine the impact of these shocks on the maize trade regime in Ethiopia. The impact of production shocks are evaluated by comparing the outlook period maize price during a normal harvest season with hypothetical parity prices for a bumper harvest and a drought season. These production shocks were introduced into the model in the 2017 outlook period.

From a policy perspective, understanding the likely impact of weather-induced and good harvest shocks on the domestic maize market and on the regional maize trade patterns are critical to provide policy alternatives for the Ethiopian government to lift maize export bans and allow private sectors to export and import maize under different domestic maize harvest conditions. This will support rules-based state interventions in the domestic maize market and would reduce regional food insecurity by strengthening the ability of markets to provide access to affordable maize to poor households. Moreover, since Ethiopia has been a major recipient of food aid, food aid agencies would also benefit from a likely impact of weather-induced shocks on maize production, market price, consumption, and government stocks.

This article is structured as follows. The "Data source and description" section describes price formation of a commodity and data sources. The "Concept of partial equilibrium modelling" and "Model structure" sections explain the analysis approaches. Findings of the study are discussed in section five. The "Conclusion and policy recommendations" section concludes and provides policy implications.

Data source and description

Ethiopia is largely self-sufficient in maize production. The self-sufficiency ratio for maize has fluctuated between 94 and 102% implying that the country is trading at an autarky trade regime (Yami et al. 2017). Hence, domestic demand and supply dynamics are expected to determine maize price formation in Ethiopia. Full historical data for the supply and demand of maize components were obtained from the United States Department of Agriculture – Production, Supply and Demand (USDA-PSD). Domestic agricultural statistical data sources including the Central Statistical Agency of Ethiopia (CSA) and the Ethiopian Grain Trade Enterprise (EGTE) were also used to supplement the USDA's data. The historical data for the supply and demand components of maize commodity balance sheet range from 2001 to 2015.

The maize crop in Ethiopia has shown tremendous growth, in both area harvested and productivity per hectare. On average, the maize area harvested expanded from 1.5 million ha to more than 2 million ha between 2001 and 2006 and 2012–2015. For the same period, the maize yield also increased substantially, from 1.86 to 2.9 tons ha^{-1}. Because of this growth, maize production has been boosted recently, surpassing 6 million MT. During 2001–2006 and 2012–2015, maize production registered a 113% growth rate, on average, from 2.8 million MT to 6.1 million MT (United States Department of Agriculture (USDA) 2015).

With regard to intra-country trade, there is evidence of maize exports from Ethiopia to other African countries since 2000 as shown in Table 1. Ethiopia exports maize grain and maize products (flour and bran) to major deficit maize markets of Sudan (former), Djibouti, and Kenya. Maize and maize products were exported consistently to Djibouti and Sudan (former). On the other hand, it was exported in only one specific year to Madagascar and Tanzania in 2004 and Kenya in 2011, respectively. The official maize export reached the highest of 23,332 tons in 2010. Similarly, negligible quantities of maize production, close to 2707 tons were exported in 2011. The 2010 and 2011 exports coincided with the 2-year period when the export ban on maize commodity had been lifted. The Ethiopian government lifted the export ban in July 2010. However, the lifting of the export ban did not last long as the government re-imposed the ban in March 2011.

Table 1 Maize export trends of Ethiopia to African countries (MT) (2000–2016)

Export destination	Export period									
	2000	2001	2002	2003	2004	2005	2006	2008	2010	2011
Djibouti										
Flour			11							
Maize	335	311	1208	705	1290	696	422		133	340
Maize bran			93							
Maize flour		11						10		
Kenya										
Maize										90
Madagascar										
Maize					2222					
Sudan (former)										
Maize						1860	251		23,199	2277
Tanzania										
Maize					5568					
Grand total (MT)	335	322	1312	705	9080	2556	673	10	23,332	2707

Source: FAOSTAT, 2019

In general, the volume of maize export is negligible compared to the domestic production level. For instance, the aggregate volume of export during 2008–2011 was less than 1% of the country's maize production. Apart from the low volume of export, the export till 2008 was not a profitable one as the domestic wholesale price was wandering within the export and import parity prices (Rashid and Minot 2010). We believe that an official commercial export was not made during 2000–2008. Perhaps the exports that were noted were accounted for by the domestic procurements by the World Food Programme (WFP) for providing humanitarian assistance to other countries.

Time series data on producer and wholesale prices of white maize and sorghum commodities were obtained from the Food and Agricultural Organization of the United Nations (FAO). Real prices were used by deflating the nominal prices by the Consumer Price Index (CPI). Regarding the developments in wholesale maize price trends, the general trend in real price levels for maize and its close substitute, sorghum, indicated that both producer price levels experienced upward swings in 2007 and 2008. Recently, both producer and wholesale sorghum and maize prices have shown a declining trend (Fig. 1). This may have been attributed to the Ethiopian government policy responses to soaring food prices.

Monthly rainfall data was obtained from the National Meteorological Agency of Ethiopia (NMA). About 82% of maize production is produced in Amhara and Oromia regions in Ethiopia (Rashid and Minot 2010). To this end, the rainfall patterns in these two regions would affect maize production in Ethiopia. From the Amhara region, rainfall data from Bahir Dar, Gondar, Dembecha, and Debre-Markos districts were used, while rainfall data from seven of the maize surplus producing districts of Oromia region, comprising Arsi-Negele, Bure (Illubabore zone), Bako, Jimma, Nekemete, Meki, and Ziway, were included in model estimation. The mean annual rainfall in the major maize producing districts is displayed in Table 2. The mean annual rainfall had fluctuated between 2096 mm in Nekemete to 692 mm in the Rift Valley moisture-stressed districts of Meki and Ziway. These rainfall amounts were favourable for maize production, as maize requires

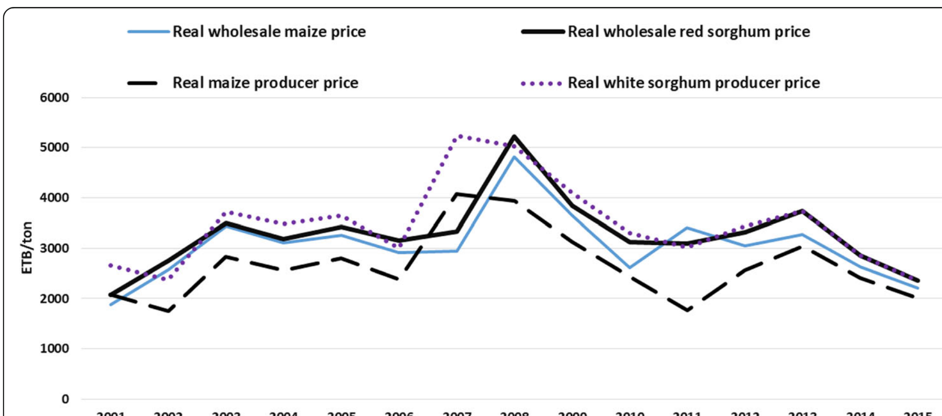

Fig. 1 Trends of real producer and wholesale sorghum and maize prices, 2001–2015. Source: Author's computation from FAO data (FAO (Food and Agriculture Organisation of the United Nations) 2015)

Table 2 Annual rainfall (mm) for major maize producing districts (1995–2014)

Regions	Districts	Elevations (masl)	Mean	Std. dev.	Min	Max
Amhara	Bahir Dar	1827	1365	304	635	1957
	Gondar	1973	1162	224	653	1761
	Debre-Markos	2446	1253	298	164	1590
	Dembecha	2117	1242	230	771	1640
Oromia	Bako	1650	1082	530	148	2381
	Jimma	1718	1466	282	831	1967
	Nekemete	2080	2096	232	1706	2551
	Meki and Ziway	1640	692	185	346	1042
	Arsi-Negele	1913	817	412	206	1486
	Bure	1750	976	442	315	1693

Source: Author's calculation using NMA data (2015)

450 to 600 mm of precipitation per season. However, there were also drought years in Debre-Markos, Bako, and Arsi-Negele.

Concept of partial equilibrium modelling

The fundamental assumption of the partial equilibrium model is the neo-classical approach, which assumes that the balance between consumption and production in the economy is maintained by producers' and consumers' profit maximizing and utility motives (Garforth and Rehman 2006; Kotevska et al. 2013). Thus, the key behavioural assumptions of economic agents in partial equilibrium models are utility and profit maximization.

Typically, partial equilibrium models include supply, demand, trade, and price linkage blocks. The supply block consists of area harvested, yield, production, and beginning stocks. The demand block consists of human consumption, feed utilization and amount retained for seed, and ending stocks. Figure 2 displays the

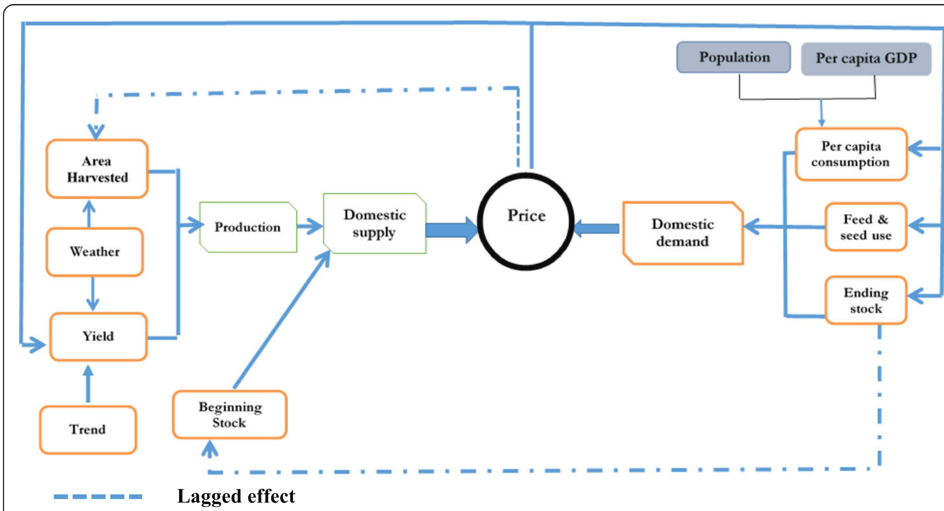

Fig. 2 White maize price formation in Ethiopia under autarky trade regime. Source: Adapted from Meyer et al. (2006)

price formation for a commodity when a country is in an autarky trade regime. Since the maize industry in Ethiopia is trading in an autarky trade regime, this graphical explanation of the behavioural relationships can capture the features of white maize market price formation in Ethiopia. The broken lines indicate lagged relationships between variables. Farmers make their decisions to plant a crop based on lagged own price and prices of substitutes. Beginning stocks equals lagged ending stocks or inventory.

Farmers' decisions to grow maize start from land allocation decisions. Maize farmers have to make an initial decision on the size of maize area to be planted. Farmers' decisions on maize area allocation depend on own price, prices of substitutes, weather conditions, and prices of inputs. Measuring the effects of the above-mentioned price and non-price related factors on farmers' land allocation decisions is called supply response analysis. One of the most important issues in agricultural development economics is supply response, since the responsiveness of farmers to economic incentives largely determines agriculture's dynamics and contribution to the economy. Furthermore, the response elasticity is also important for policy decision-making as it gives an indication of the factors that constrain farmers' responsiveness to output price changes. According to Tripathi (2008), the agricultural supply response represents change in agricultural output due to a change in agricultural output price. The concept of supply response is dynamic and different from supply function which is a static concept. The supply function describes a price quantity relation, where all other factors are held constant. The response relation is more general concept; it shows the change in quantity with changes in prices as well as supply shifters and, therefore, approximates to the long-run, dynamic concept of supply theory.

Maize is a stable food crop in Ethiopia. As a result, the Ethiopian government's main target is to maintain food self-sufficiency and improve the marketability of the commodity. Therefore, policies that encourage greater production of maize and the transition from a subsistence to a market-oriented farming system necessitate the carrying out of supply response studies. In annual agricultural crop production, farmers observe the output price after production has been obtained. As a result, farmers' planting decisions are made based on price expectations at harvesting time. Hence, producers' price expectations play a pivotal role in acreage allotment for annual crops. In general, two models are widely used to analyse the elasticities of supply response in annual agricultural crops. These approaches are the Nerlovian expectations and partial adjustment models. In the Nerlovian expectations model, farmers make their production decisions based on expectations of future prices. The assumption is that a rational farmer is more likely to respond to the price he or she expects, rather than to the price in the previous period, and the expected price will depend only to a limited extent on the actual price in the previous period.

On the other hand, the Nerlovian adjustment model assumes that farmers form their expectations about what will happen in the future based on what has happened in the past. Farmers, especially in developing countries, are facing problems in obtaining relevant market price information. Therefore, rational expectation behaviour is not relevant in the absence of future market information. Although the Ethiopian government has recently opened an exchange market, the trading of cereals including maize and wheat is relatively negligible, as compared with high-value exportable crops. Hence, this study has assumed that the Nerlovian adjustment model would be adequate for the Ethiopian maize market context.

According to Nerlove, the desired level of supply (Q_s^*) can be expressed as a function of expected price and exogenous supply shifters:

$$Q_s^* = \eta + \beta P_t + c\, Z_t \tag{1}$$

where Q_s^* is desired level of supply, P_t is expected price, and Z_t is a set of exogenous supply shifters such as technological progress, weather related factors, and so on.

Actual supply level (S_t) may differ from the desired ones because of the adjustment lags of variable factors. Therefore, it is assumed that actual level of supply would only be a fraction δ of the desired level of supply.

$$S_t = (1{-}\delta)S_{t-1} + \delta Q_s^* + \epsilon_t \tag{2}$$

Farmers' expected price can be observed at harvest time. So, we have to formally describe how decision makers form expectations based on the knowledge of actual and past price and other observable information. We may think that farmers maintain in their memory the magnitude of the mistake they made in the previous period and learn by adjusting the difference between actual and expected price in t-1 by a fraction λ (Tripathi 2008).

$$P_t = \lambda P_{t-1} + (1{-}\lambda)P_{t-1} \tag{3}$$

The first step is substituting Eq. 1 into Eq. 2, and it yields Eq. 4

$$S_t = \eta\delta + (1{-}\delta)S_{t-1} + \delta\beta P_{t-1} + c\, Z_t + \epsilon_t \tag{4}$$

The second step is to substitute Eq. 3 into Eq. 4. This substitution yields

$$S_t = \eta\delta + (1{-}\delta)S_{t-1} + \delta\beta\,[\,P_{t-1} + (1{-}\lambda)P_{t-2} + \dots\dots\dots.] + c\, Z_t + \epsilon_t \tag{5}$$

With the advancement of time series analysis, serious methodological issues have been raised on the Nerlovian agricultural supply response model and its estimation techniques. For instance, the Nerlovian model has failed to capture the full dynamics of agricultural supply response (Thiele 2000). The model is also incapable of providing an adequate distinction between short- and long-run elasticities (McKay et al. 1998). Furthermore, the analysis may use non-stationary series, which is a source of spurious regression (Granger and Newbold 1974). To account for these shortcomings of the Nerlovian model, recent studies on supply response have proposed cointegration models. This study also applied a cointegration approach of the error correction model (ECM) to estimate maize supply response. To the best of author's knowledge, only Alemu et al. (2003) have applied this approach in grain supply response estimation in Ethiopia.

After a producer decides on how many hectares of land to allocate for maize production, the maize yield, which is influenced by weather conditions, determines the total maize production. Total maize production or domestic production is obtained by multiplying the maize area harvested by the yield level. In the demand block, human consumption, feed and seed consumption, and ending stocks determine the total demand for Ethiopian white maize. Following the law of demand, human and feed consumption are expected to have a downward slope or negative relationship with price. A positive relationship between income, population, and human consumption is expected. Ending stocks comprise the demand for storage and speculation, which indicates a negative relationship between ending stocks and prices.

Model structure

A single commodity partial equilibrium framework was used to investigate the maize price formation and a likely impact of a bumper harvest and drought shocks on the maize market. The maize market price formation comprises three blocks: supply and demand blocks and model closure (see Fig. 2). A commonly used approach to estimate single equations is ordinary least square (OLS). However, this approach is exposed to the problem of spurious regression in the case of non-stationary variables. Since the estimated parameter values from single equations are used for baseline projections, any misspecifications in the initial stage can contaminate the next stage estimations of baseline projections and model simulation outcomes. In an attempt to overcome this misspecification, the present study estimated the behavioural equations using a combination of OLS (for stationary equations) and an error correction model (ECM) (for non-stationary and cointegrated series). Based on the results of the augmented Dickey-Fuller (ADF) unit root test (Dickey and Fuller 1979), maize area harvested and ending stock equations were estimated using ECM, while maize yield and per capita maize consumption equations were estimated using OLS. Graphical and statistical methods are used to evaluate the adequacy of the model. The model specifications for the behavioural equations are presented in Table 3.

The findings from the maize supply response suggest that farmers respond very little to price in planning their maize acreage (see Table 4). The low price elasticities of supply can be attributed to the subsistence nature of maize farming practices in Ethiopia. Farmers are more concerned for household consumption than market incentives. Maize is mainly produced for household consumption (> 75%). It is only 13% of maize production that is marketed (Central Statistical Agency (CSA) 2015). The estimated income elasticity was 0.012, suggesting that a 10% increase in real per capita GDP would increase per capita maize consumption by 0.12%.

Empirical results

The results section begins by presenting findings of selected behaviour equations such as maize yield and per capita maize consumption equations and then follows with analysis of the dynamic effects of different production shocks in the developed partial equilibrium model for the Ethiopian white maize market. Here, we are particularly interested in examining the short-run and long-run impact of a bumper harvest and weather-induced shocks on the maize market outlook period from 2017 to 2025. The introduction of these shocks into the system takes into account the current trends in the maize market in Ethiopia.

Table 3 Maize model specifications

Area harvested[a]	$H^m = \delta_0 + \delta_1 P^m{}_t + \delta_2 S^P{}_t + \delta_3 R^L{}_t + \delta_4 T_t + \varepsilon_t$ 1(a)
	$H^m = \theta_0 + \theta_1 \Delta P^m{}_t + \theta_2\, \Delta\, P^s{}_t + \theta_3 \Delta R^L{}_t - \lambda\, (Y_t - \alpha_0 - \alpha_1 P^m{}_t - \alpha_2 P^s{}_t - \alpha_3 R^L{}_t - \alpha_4 T_t) + v_t$ 1(b)
Yield	$Y^m = R^P{}_t + IR^m{}_t + SD^i{}_t + T^L_t$
Production	$M^P = H^m * Y^m$
Beginning stocks	$B^s = E^s_{t-1}$
Supply	$X^m = M^P + B^s + I^m$
Ending stocks	$E^s = B^s + M^P - P^w + A^f$
Per capita consumption	$C^m = S^w - P^w + G^d + S^{05} + S^{11} - T_t$
Human consumption	$\text{HCons}^m = C^m * Pop$
Domestic use	$\text{DUSE}^M = \text{FEED}^m + \text{SEED}^m + \text{HCons}^m$
Demand	$D^m = \text{EXPO}^m + \text{DUSE}^M + E^s$
Model closure	$X^m = D^m$ (market clearing price)

Variable names
H^m = Planned maize acreage proxied by area harvested in thousand hectares
$P^m{}_t$= Deflated maize producer price (ETB/ton). It is obtained by dividing the nominal maize producer price by CPI indexed at the 2010 price
$S^P{}_t$= Real producer prices for competing crop (sorghum) (ETB/ton)
$R^L{}_t$= Rainfall amount (mm) prior to sowing period
T_t = a time trend variable used as a proxy for technological progress in maize farming
Y^m = Maize yield (ton/ha)
R^P = Rainfall amount for production season. It includes average rainfall (mm) for the months of June, July, August, and September
IR^m = Irrigated maize area (ratio)
SD^i = Maize planted with improved seed (ratio)
T^L_t = Linear trend to capture the overtime effects of maize technological improvement on yield
M^P= Maize production
B^s = Beginning stock
E^s_{t-1}= Lagged ending stock
X^m = Total maize supply
I^m = Maize import
P^w= Real wholesale maize price (ETB/ton)
A^f= Wheat food aid quantity (tons)
C^m= Per capita maize consumption
S^w=Real wholesale sorghum price (ETB/ton)
G^d=Real per capita GDP
S^{05}= a shift variable for the period of soaring food prices in the domestic grain market. It takes 1 for the period since 2005 and 0 otherwise
S^{11}=a shift variable for the export ban; 1 for the period since 2011 and 0 otherwise
Pop= Ethiopia population
HCons^m = Human maize consumption
DUSE^M = Total domestic use of maize
FEED^m = Feed use of maize
SEED^m = Seed use of maize
D^m = Total maize demand
$EXPO^m$= Maize export
[a]The equation for maize supply response was estimated following the two-stage procedure proposed by Alemu et al. (2003). First, a static long-run equilibrium regression is given by Eq. 1(a), was estimated. Second, a dynamic error correction model as specified in Eq. 1(b) was estimated by including the lagged residual from Eq. 1(a) (of course, the residual from Eq. 1(a) should be stationary). The planned maize acreage is proxied by area harvested. It has been common practice to proxy an acreage decision by area harvested because of the lack of data on area planted (Meyer and Kirsten 2010). Area harvested is preferred to output because farmers have more control on the former than on the latter. This is because agricultural output is subject to fluctuations, which are beyond the control of farmers.

Maize yield

The maize yield equation was estimated as a function of rainfall, maize area under irrigation, improved seed utilization, and technological improvement over time. The rainfall pattern during land preparation, planting, and maturity stages influences the maize yield. The result of the maize yield equation is presented in Table 5.

Table 4 Key findings from behavioural equations

Variables	Elasticity
Short-run price elasticities of supply	0.062
Long-run price elasticities of supply	0.167
Own elasticity of demand	− 0.322
Cross price elasticity of demand	0.074
Income elasticity of demand	0.012
Elasticity of maize consumption over time	− 0.0071

In the yield equation, the trend variable appeared with the expected positive sign, and it is statistically significant at 5% significance level. Technological introduction and progress in the maize commodity over the years has, thus, positively contributed to maize yield improvement in Ethiopia. Maize is grown in almost all agrological conditions in Ethiopia, from rainfed highland areas to moisture-stressed lowland areas. Given this wide adaptability, large numbers of households are growing the crop; close to nine million smallholder farmers are growing maize in Ethiopia, more than any other crop being grown in the country. With regard to maize productivity, Ethiopia has registered commendable growth in maize yields (see Fig. 3). The 5-year average maize yield between 2011 and 2015 was estimated at 2.94 tons ha^{-1} (United States Department of Agriculture (USDA) 2015, quoted by Gurmu et al. 2017). Maize yields reached a historic high level of 3.25 tons ha^{-1} in 2013.

It is important to highlight the main drivers that have contributed to the dramatic change in maize yield and production in Ethiopia. Here, we list three success factors of the maize green revolution in Ethiopia. Firstly, there is relatively good coordination among the various actors involved in maize technology promotion and popularization. The success of maize technology promotion and adoption, including the introduction of hybrid, stress-tolerant and Quality Protein Maize varieties (QPM) in Ethiopia is the result of strong collaborative work by private and public seed enterprises, NGOs (Sasakawa Global 2000), and the national and international research institutes. The introduction of high-yielding and

Table 5 Results for maize yield equation

	(1)	(2)
Variables	Robust OLS	Elasticity
IRRIG	0.308 (28.14)	0.003
SEED	0.381 (1.059)	0.038
LNTREND	0.460** (0.191)	
RAINP	0.005 (NA)	1.65
Constant	− 2.4 (1.110)	
Observations	15	
Adjusted R^2	0.61	
F statistics	6.49**	

Robust standard errors in parentheses; **$p < 0.05$, *$p < 0.1$; no standard errors are reported for the rainfall variable. Because of undesirable coefficient signs, we modified the value of the rainfall variable using a synthetic estimation technique. A synthetic elasticity coefficient value of 1.65 was used to obtain the rainfall coefficient. Given the high dependency of maize production on rainfall, the use of a 1.65 elasticity value is reasonable

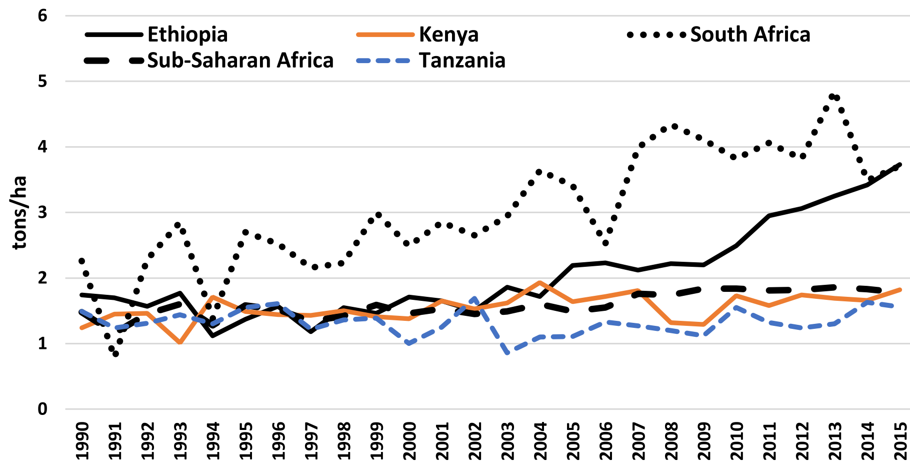

Fig. 3 Maize yield in major Sub-Saharan African countries (1990–2015). Source: Author's calculation using USDA data (United States Department of Agriculture (USDA) 2015)

stress-tolerant improved maize varieties has played a key part by replacing the traditional low-yielding maize varieties in Ethiopia. Since 1973, the National Agricultural Research System (NARS) has released a total of 61 maize varieties (Abate et al. 2015). Currently, various institutions are working together to improve maize production and its contribution to food security in Ethiopia. The International Maize and Wheat Improvement Centre (CIMMYT) is the main source of maize germplasm. The Bako Agricultural Research Institute, under the Ethiopian Institute of Agricultural Research (EIAR), has the mandate to coordinate maize research and technology adaptation and generation in Ethiopia. Regional and federal seed enterprises multiply basic and certified maize seed for wider dissemination. Moreover, private sector participants, such as Pioneer Hybrid, are also involved in hybrid maize seed production and marketing to farmers. The Ministry of Agriculture (MoA) and EIAR have the mandate to popularize and demonstrate newly released maize varieties and empower farmers through subsequent training sessions. The recently established Agricultural Transformation Agency (ATA) is also working on maize value chain development in Ethiopia

Secondly, the focus given by the Ethiopian government to modernizing the agricultural extension system and improving its accessibility to farmers needs great appreciation. The introduction of new technologies alone does not guarantee yield improvement, unless accompanied by a modern extension system. The agricultural extension approach of Ethiopia could serve as a role model for Africa. In every district, the government has assigned three professional agricultural extension workers to help farmers with crop technology, livestock husbandry, and sustainable land management practices. Since 2000, Ethiopia has trained 63,000 extension agents. This has improved the extension agent-to-farmer ratio. Ethiopia's extension agent-to-farmer ratio is estimated at 1:476, compared to 1:1000 for Kenya, 1:1603 for Malawi, and 1:2500 for Tanzania (Kassie et al. 2015). This achievement is believed to improve the uptake of modern farm-enhancing technologies. Thirdly, the even distribution of rainfall over the last two

Table 6 Results for per capita maize consumption

Variables	(1) Robust OLS	(2) Elasticity
RMPRICE	− 0.0045 (0.008)	− 0.322
RPCGDP	0.117 (0.167)	0.012
RSORGPRICE	0.007 (0.008)	0.074
SHIFT05	11.12* (5.592)	
SHIFT2011	14.65*	
TREND	− 2.894 (3.867)	− 0.0071
Constant	12.72 (22.567)	
Observations	15	
Adjusted R^2	0.64	
F statistics	5.086**	

Robust standard errors in parentheses; ***p* < 0.05, **p* < 0.1

decades has played a favourable role in increasing maize productivity in Ethiopia (see Table 2).

Per capita maize consumption

The findings for the drivers of per capita white maize consumption in Ethiopia are illustrated in Table 6. Per capita maize consumption is modelled as a function of own price, price of substitutable crop (i.e. sorghum), real per capita GDP, and two shift variables capturing the soaring food price phenomena and changes in the policy environment from free trade to export ban. A trend variable is also incorporated to examine the changing trend in the consumption habits of maize consumers over time.

All the estimated variables in the per capita white maize consumption have the expected signs. Economic theory has taught us that basic goods tend to have an inelastic demand. Maize is a basic commodity in Ethiopia and, therefore, as the maize price increases, consumers do not immediately alter their usual consumption of maize. Instead, they decrease their maize consumption moderately. This is evidenced by the negative elasticity coefficient of the real wholesale maize price, which is 0.322, implying that a 10% increase in real wholesale maize price would lead to a decrease in per capita maize consumption by 3.22%. The estimated income elasticity is 0.012, suggesting that a 10% increase in real per capita GDP would increase maize per capita consumption by 0.12%.

The trend variable appeared with a negative sign, indicating the decline in the share of maize in the consumption basket of consumers, over time. This could be attributed to the increase in urbanization. It has been well documented that owing to urbanization, people tend to move away from the consumption of root crops and coarse grains to wheat and rice. However, the effect of the trend variable is small, which is an indication that the composition of food baskets in Ethiopia is fairly constant. The elasticity for the trend variable was − 0.0071, which implies that in each year, per capita maize consumption decreases by

0.071%. The elasticity is small because the majority (85%) of the Ethiopian population reside in rural areas. In the rural areas of Ethiopia, maize is the main staple food crop. Hence, the decreasing trend being captured at the national level is because of changes in the diets of urban consumers. In urban areas, wheat and teff crops are the most preferred crop for consumption (Worku et al. 2015).

The real wholesale sorghum price incorporates the effect of substitutes in maize consumption in Ethiopia. The sorghum price has a positive effect on maize consumption: if the price of a substitute crop increases, maize consumption will increase. However, maize consumption is inelastic to the sorghum price. A 10% increase in the sorghum price would lead to an increase in per capita maize consumption by 0.74%. Both shift variables that take into account the effect of soaring food price phenomena and the export ban on maize consumption were positive and significant at 10% significance level. Maize is one of the food crops that have experienced soaring food prices in the domestic grain market. The positive and significant relationship of maize per capita consumption to high market price environment is not a surprise. As stated earlier, maize is mainly produced for home consumption. Therefore, the decision to produce maize is mainly influenced by subsistence requirements, rather than by market price dynamics. One possible reason for the positive relationship between maize consumption and price hikes could be that farmers may increase the marketing of high price commodities. An increase in the marketability of other cereals could increase the use of maize for household consumption. Maize consumption has shown an upward trend since 2005. On average, maize per capita consumption increased by 46% from 31.8 kg per person during 2001–2004 to 46.57 kg per person during 2005–2015.

The shift variable (SHIFT2011), capturing the effect of an export ban on maize consumption, is also significant and positive. This result is consistent with a prior expectation and economic theory that an export ban in the face of high domestic maize production would lower maize price in the domestic market. As a result, consumers would enjoy low prices through increasing their maize consumption. However, this assertion would work only if the export of maize became profitable. Removing an export ban has no effect if exports are not profitable.

Impact of a bumper harvest

As outlined above, Ethiopia is one of the few countries in Sub-Saharan Africa (SSA) that has attained > 3 tons per hectare in maize yields. This is regarded as a big achievement for a smallholder-dominated maize producer country such as Ethiopia. Ethiopia exceeded 3 tons per hectare in the 2012 and 2013 production seasons (see Fig. 3). The average maize yield during these two periods was 3.2 tons ha^{-1}. This figure represents a 50% increase, compared with the preceding eleven years (2001–2011) which had a maize yield average of 2.10 tons ha^{-1}. The success in maize yield improvement emanates from a better breeding strategy that considers the heterogeneous typology of maize production in Ethiopia. The current maize yield is 2.9 tons ha^{-1}, and there is still much scope for improving the current maize yield through the intensification of chemical fertilizer utilization, conservation farming, mechanization, and investment in irrigation infrastructure. Therefore, it is reasonable to believe that the country can replicate the success in maize productivity with the expected improvement in government investment in the above-mentioned infrastructural facilities. To this end, we introduced a 20% shock in maize yield into the partial equilibrium maize model for Ethiopia. The shock was introduced in the 2017 baseline period.

The dynamic responses of the maize sub-sector to a bumper harvest are summarized in Table 7. The impact of the yield simulation is more pronounced and persistent for maize ending stocks and the nominal maize price. As compared with the baseline, a 20% increase in the maize yield could reduce the maize price substantially, by 81%. There have been previous experiences of maize price collapse of such magnitude. In Ethiopia, maize prices collapsed considerably whenever there are bumper harvests. This was the case in 1999 and 2002 (RATES 2003). For instance, following the 2 years consecutive bumper harvests, maize prices dropped by about 80% in 2002. As a result, the Ethiopian government procured 18,000 MT of maize, of which 11,000 MT was exported. Furthermore, a 20% positive yield shock would

Table 7 Impact of a bumper harvest on the maize market

Affected components	2017	2018	2019	2020	2021	2022	2023	2024	2025
Maize yield	Tons/ha								
Baseline	2.86	2.91	2.89	2.88	2.92	2.93	2.96	2.94	3.00
Scenario	3.43	2.91	2.89	2.88	2.92	2.93	2.96	2.94	3.00
Absolute change	0.57	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
% change	20%	0%	0%	0%	0%	0%	0%	0%	0%
Maize production	Thousand tons								
Baseline	6890	7193	7324	7498	7759	7972	8242	8374	8755
Scenario	8262	7193	7324	7498	7759	7972	8242	8374	8755
Absolute change	1373	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
% change	20%	0%	0%	0%	0%	0%	0%	0%	0%
Domestic maize use	Thousand tons								
Baseline	6858	7126	7277	7455	7692	7909	8165	8325	8661
Scenario	7849	7337	7372	7498	7711	7918	8169	8326	8662
Absolute change	991	211	95	43	19	9	4	1	0
% change	14%	3%	1%	1%	0%	0%	0%	0%	0%
Ending stocks	Thousand tons								
Baseline	441	509	556	599	666	728	805	854	948
Scenario	823	680	632	632	681	734	808	855	949
Absolute change	382	171	76	34	15	6	3	1	1
% change	87%	34%	14%	6%	2%	1%	0%	0%	0%
Nominal wholesale maize price	ETB/ton								
Baseline	5733	5599	5845	5989	5717	5465	4855	4742	3759
Scenario	1061	4545	5347	5756	5609	5416	4833	4732	3755
Absolute change	− 4672	− 1054	− 498	− 233	− 108	− 49	− 22	− 10	− 4
% change	− 81%	− 19%	− 9%	− 4%	− 2%	− 1%	0%	0%	0%

Source: Model outcome

increase maize ending stocks by 87% in the short run, and the effect will also continue in the long run. A positive change in maize yield would lead to an increase in ending stocks by 34%, 14%, 6%, and 2% in 2018, 2019, 2020, and 2021, respectively. A moderate impact is noticed on domestic maize use; a 20% increase in maize yield could increase domestic maize use by 14%.

The maize area harvested has remained unaffected by the 20% positive increase in maize yield. The non-responsiveness of maize area harvested to the yield shock raises some doubt on the estimation method. As illustrated above, maize area is estimated differently from the rest of the behavioural equations. We estimated the maize supply response using the ECM in order to account for the spurious regression problem. We then plugged the short-run elasticity values into the partial equilibrium model. This may have created disconnection between the maize area harvested and the price model.[4]

Impact of a drought

Staple food crops, such as maize, are prone to weather-related shocks in Ethiopia. In 2015, maize production and consumption subsided owing to the effect of drought (El Nino). Drought reduced maize production by 23% in 2015 (United States Department of Agriculture (USDA) 2017). This is not surprising because the majority of maize is produced in a rainfed farming system. Only 2% of maize production is grown under irrigation (CSA, 2015). Therefore, understanding the possible impact of rainfall shocks on the maize market is crucial for designing an early warning system and a price stabilization policy. The analysis would also help food aid agencies to accurately project consumption shortfalls and food aid need.

Table 8 presents the findings from the simulation analysis. The shocks were invoked into the system in 2017. From the analysis, it can be seen that the components most affected by drought are ending stocks and maize price. The effects are also more persistent in these two components. A 10% combined decrease in rainfall amount during the planting and the main season maize production months in the major maize-producing areas would decrease maize ending stocks by 64% in the short run. The effect also continues in the long run. On the other hand, the effect of a drought would increase maize prices by 61%. In the long run, a 10% combined decrease in rainfall amount during the planting and the main season maize production months would lead to an increase in maize prices by 14%, 6%, and 3% during 2018, 2019, and 2020, respectively.

Should maize be exported?

An interesting follow-up question would be whether shocks (a bumper harvest) in the maize industry would necessitate a temporary lift of the export ban on maize. From a policy perspective, addressing this question is important to provide policy alternatives for the Ethiopian government as to whether to lift the export ban temporarily in case of a good harvest season and to allow private traders to export

[4]The maize supply response equation was estimated using an Error correction model to overcome spurious regression problems. Hence, we used the first differenced maize price variable as opposed to lagged prices. This appears to have caused unresolved issues with the scenario analysis.

Table 8 Impact of a drought

Affected components	2017	2018	2019	2020	2021	2022	2023	2024	2025
Area harvested	Thousand hectare								
Baseline	2408	2472	2536	2602	2661	2725	2789	2850	2922
Scenario	2366	2472	2536	2602	2661	2725	2789	2850	2922
Absolute change	− 42	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
% change	− 2%	0%	0%	0%	0%	0%	0%	0%	0%
Maize yield	Tons/Ha								
Baseline	2.86	2.91	2.89	2.88	2.92	2.93	2.96	2.94	3.00
Scenario	2.48	2.91	2.89	2.88	2.92	2.93	2.96	2.94	3.00
Absolute change	− 0.38	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
% change	− 13%	0%	0%	0%	0%	0%	0%	0%	0%
Maize production	Thousand tons								
Baseline	6890	7193	7324	7498	7759	7972	8242	8374	8755
Scenario	5871	7193	7324	7498	7759	7972	8242	8374	8755
Absolute change	− 1019	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
% change	− 15%	0%	0%	0%	0%	0%	0%	0%	0%
Domestic maize use	Thousand tons								
Baseline	6858	7126	7277	7455	7692	7909	8165	8325	8661
Scenario	6123	6969	7206	7424	7678	7903	8162	8324	8660
Absolute change	− 735	− 157	− 70	− 31	− 14	− 6	− 3	− 1	− 1
% change	− 11%	− 2%	− 1%	0%	0%	0%	0%	0%	0%
Ending stocks	Thousand tons								
Baseline	441	509	556	599	666	728	805	854	948
Scenario	157	382	500	574	655	723	803	853	948
Absolute change	− 284	− 127	− 56	− 25	− 11	− 5	− 2	− 1	0
% change	− 64%	− 25%	− 10%	− 4%	− 2%	− 1%	0%	0%	0%
Nominal wholesale maize price	ETB/ton								
Baseline	5733	5599	5845	5989	5717	5465	4855	4742	3759
Scenario	9201	6382	6215	6162	5797	5502	4872	4750	3762
Absolute change	3469	783	370	173	80	37	17	8	3
% change	61%	14%	6%	3%	1%	1%	0%	0%	0%

Source: Model outcome

maize. This can be done by comparing the domestic maize prices with the IPP and EPP under different domestic maize harvest scenarios.[5] It should be noted that this comparison is made by assuming the maize export ban will remain unchanged during the simulation period. In practice, it is unlikely to expect a country not to import and export a commodity in times of drought and bumper harvests. However, this analysis at least allow us to examine the dynamic impact of production shocks

[5]Several assumptions were made to conduct the maize parity price analysis under different domestic maize harvest scenarios. Some of the assumptions include port handling, loading/unloading, and inland transport costs from Djibouti port to the central Addis Ababa wholesale maize market were assumed to remain constant during the simulation period of 2017. Apart from the 5% import tariff rate, other policy effects were not incorporated into the calculations of the EPP and IPP analysis. Furthermore, the net trade is assumed to be zero for the periods from 2016 to 2025.

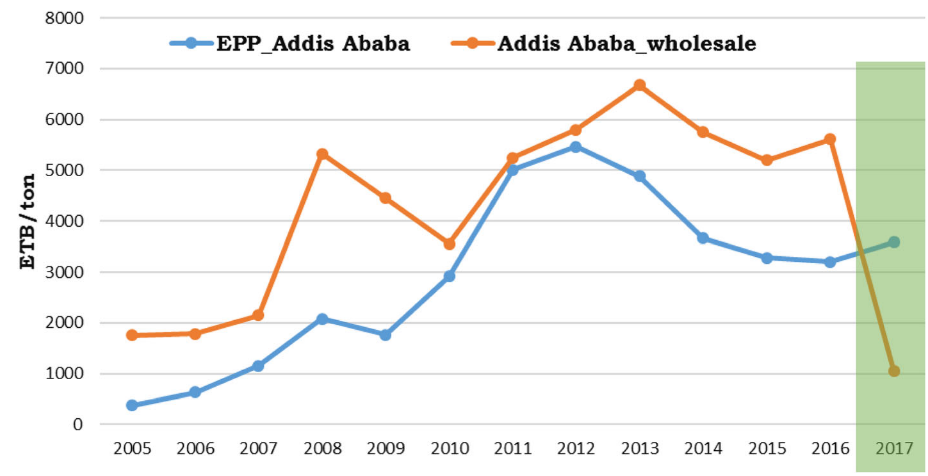

Fig. 4 White maize export parity price analysis with scenario 1, 2005–2017. Note: Export parity analysis is calculated using the US No 2, yellow maize, Gulf of Mexico. Source: Author's calculation

on the profitability of maize import and export decisions without incorporating a trade equation into the partial equilibrium maize model for Ethiopia.

Scenario 1: A bumper harvest

As we noted in the yield simulation analysis, a 20% increase in the maize yield would decrease the maize price by 81%. Because of an increase in the maize yield, the domestic maize price would become lower than the export parity price for the shock period. In the short run (within the year), the domestic maize price declines 70% (110 USD/t) below the lower threshold EPP. This makes maize exports profitable and has resulted in a trade regime shift from autarky to export parity trade regime for the Ethiopian white maize market (Fig. 4). In this scenario, therefore, lifting the export ban on maize would be an advisable policy option for curbing further reductions in the maize price. Removal of the export ban would increase the domestic maize prices above what the prices would be under the ban. This would, in turn, encourage domestic maize producers and private traders who operate in the maize market. Complete results are illustrated in Table 11 in Appendix.

Scenario 2: A drought season

As stated above, the effect of a drought would increase the maize price by 61% in the short run. This has resulted in the domestic wholesale maize price moving over the upper threshold IPP by 46% (126 USD/t). As a result, maize imports would become profitable (Fig. 5).

Potential exportable markets

Ethiopia could possibly export maize to the deficit South Sudan and Kenyan maize markets. South Sudan has increased maize import because of a decrease in sorghum imports from North Sudan. Maize imports increased from 176 thousand

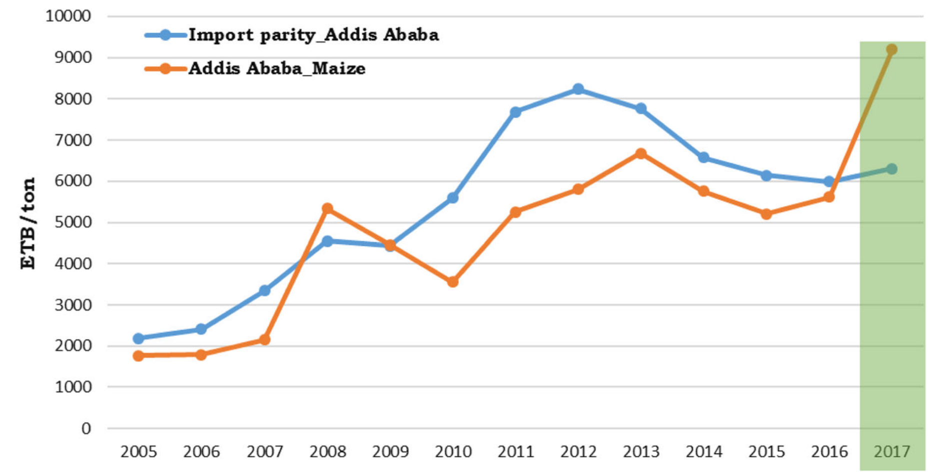

Fig. 5 Import parity price analysis for white maize with scenario 2, 2005–2017. Note: Import parity analysis is calculated using the US No 2, yellow maize, Gulf of Mexico. Source: Author's calculation

tons in 2009 to 583 thousand tons in 2013. Moreover, the domestic demand for maize has increased; and per capita maize consumption is higher than per capita sorghum consumption in Juba (Dorosh et al. 2016). The other export destination market could be the Kenyan maize market, through the Moyale border. In this section, we test long-run relationships between Addis Ababa maize market prices with South Sudan and Kenya regional maize markets using the Johansen and Juselius (1990) cointegration approach. The results are given in Table 9.

Having found that all maize price series are integrated of order one I (1), we proceed by estimating the presence of a long-run relationship using Trace and Maximum-eigenvalue test statistics (Table 10). Based on the trace test statistics, we found no cointegration between Addis Ababa and Kenya's maize markets at Nairobi and Mombasa. The absence of a long-run relationship could be attributed to high transport costs linking Ethiopia with Kenya. The average wholesale monthly

Table 9 Johansen cointegration tests between regional maize markets

Market pairs	Sample period	Lag length	Hypothesis	λ_{trace}	λ_{max}
Nairobi-Addis Ababa	2006 M01–2017 M01	1	$r = 0$	12.26 (12.32)	12.25** (11.22)
			$r \leq 1$	0.01 (4.13)	0.01 (4.13)
Mombasa-Addis Ababa	2006 M01–2017 M01	1	$r = 0$	10.37 (12.32)	10.31 (11.22)
			$r \leq 1$	0.065 (4.13)	0.065 (4.13)
Juba-Addis Ababa	2011 M08–2017 M01	1	$r = 0$	15.71** (12.32)	15.66*** (11.22)
			$r \leq 1$	0.052 (4.13)	0.052 (4.129)
Juba-Addis Ababa with shift dummy	2011 M08–2017 M01	2	$r = 0$	22.15*** (12.32)	22.03*** (11.22)
			$r \leq 1$	1.53 (4.13)	1.53 (4.13)

***, ** significance levels at 1% and 5%; *r* is the number of cointegrating vectors; lag length is selected using Akaike Information Criteria (AIC); critical values in parenthesis; all maize prices series are converted to logarithms; South Sudan received independency in July 2011. Therefore, Juba's maize price is from August 2011 onward

Table 10 Vector error correction model results for Juba and Addis Ababa market pairs

Coefficients	Cointegrating vector and adjustment coefficient
P_{t-1}^{ETH}	1.139**
ECT_{t-1}	− 0.236*
Half-life	2.57
Short-run parameters	
ΔP_{t-1}^{JUBA}	− 0.209
ΔP_{t-2}^{JUBA}	0.073
ΔP_{t-1}^{ETH}	− 0.618
ΔP_{t-2}^{ETH}	− 1.007
Shift13	0.076*
Model specification tests	
LM (3) test	0.71
Adj. portmanteau test	0.39
Normality test	438***
MARCH-LM test	54.77**
ARCH LM test	0.36

Half-life is computed as $h = [\ln(0.5)/(\ln(1+\alpha)]$, where α is the error correction term (ECT_{t-1}) and interpreted in months; adj. portmanteau test denotes adjusted portmanteau test which has more powerful small sample properties than the standard portmanteau test (see Lütkepohl and Krätzig 2004, 127); MARCH-LM test denotes multivariate ARCH test; ***, ** reject the null hypothesis at 1 and 5% significance levels, respectively

white maize price from January 2006 to January 2017 in Addis Ababa was 256 USD/ton, while it was 314 USD/ton in the Nairobi and 315 USD/ton in the Mombasa maize markets. According to Rashid et al. (2010), even a price difference of 100 USD/ton would not trigger profitable maize exports because of the high transport costs on the routes from Addis Ababa to Nairobi. The section between Awassa and Moyale in Ethiopia, and the section between Moyale and Marsabit, are in particularly bad condition. In addition, there are occasional security problems between Moyale and Marsabit. The poor road infrastructure and security risks may raise transportation costs, which reduce the export parity price in Ethiopia (Minot 2013). However, in the simulation analysis, because of a 20% positive yield shock, the Addis Ababa wholesale maize price could decrease by 110 USD/ton below the export parity price. This may be enough to stimulate profitable maize exports to Kenya.

South Sudan has experienced a renewed civil war since December 2013. Although a peace agreement was signed in 2015, the war continues. To account for the impact of the renewed civil war in the cointegration rank, a shift dummy variable was incorporated. The results for the cointegration rank test, with and without a structural shift variable, are reported in Table 9. In both cases, the trace and maximum eigenvalue test statistics rejected the null of zero cointegrating vector ($r = 0$) in favour of one cointegrating vector. Thus, cointegration between the Juba and Addis Ababa maize markets presents in both cases. The only difference is that the value of the test statics increase when we take into account a structural break for the renewed conflict. This makes sense because, in the presence of war, transaction costs are likely to increase and thus reduce the possibility of cointegration.

Evidence of cointegration between the Addis Ababa and Juba maize markets was not expected because of two reasons. Firstly, the cross-border trade between Ethiopia with South Sudan faces high risks and transportation costs, making maize export less profitable for traders. However, our results indicated that the occurrence of war does not fully impede trade and price signal flows across spatial maize markets. These results are in line with the findings of Dorosh et al. (2016). Secondly, the maize export ban is expected to impede trade between regional maize markets. One possible explanation for the presence of cointegration could be that, because of the proximity of South Sudan to Ethiopia, trade flows might not be the only price adjustment mechanism. Instead, these two regional maize market prices may follow each other through information flows, which might bring prices back to the equilibrium state in the long run. In recent years, there are a large body of literature on spatial market integration that suggest the importance of information flows as one means of mechanisms that brings markets into equilibrium state. Information flows, which are one of the overlooked and underappreciated elements of market equilibrium, may contribute to spatial market integration in the absence of physical trade flows between markets (Stephens et al. 2008). However, the speed of price adjustment to the previous year disequilibrium is low. As reported in Table 10, it takes more than 2 months for the Juba maize market to correct 50% of Addis Ababa maize price shocks.

Conclusion and policy recommendations

In this article, we examine the dynamic effects of weather-induced and bumper harvest shocks on the developed partial equilibrium model for the Ethiopian white maize market. From the yield simulation analysis, we found that a 20% increase in maize yield would result in an increase in maize production by 20%. The impact of the yield simulation was more pronounced and persistent on maize ending stocks and the maize price. As compared with the baseline, a 20% increase in the maize yield would reduce the maize price by 81%. On the other hand, the occurrence of a drought would increase the maize price by 61% in the short run.

We have also investigated the possible impact of such shocks on the profitability of maize import and export decisions. We demonstrated that, owing to a 20% increase in the maize yield, the domestic maize price would become lower than the export parity price for the shock period. In the short run (within the year), the domestic maize price would fall 70% below the lower threshold EPP. This makes maize exports profitable and shifts the trade regime from autarky to an export parity regime. In this scenario, therefore, the lifting of the export ban on maize would be an advisable policy option for cushioning further reductions in the maize price. Therefore, if a maize harvest is expected to be above average, it is advisable for the government to lift the export ban on maize. Removing the export ban on maize would set a limit on the domestic price of maize equal to the export parity price. This would keep farmers from being discouraged by low maize prices during good harvest seasons. On the other hand, the effect of drought would result in the domestic wholesale maize price moving over the upper threshold IPP by 46% (126 USD/t). As a result, maize import would become profitable.

The frequent and unpredictable lifting and re-imposition of export bans since 2006 have created uncertainty in the maize market in Ethiopia (see Food and Agriculture Policy Decision Analysis Tool (FAPDA) 2017). Thus, intensive dialogue between the government and the private sector about trade policy decision-making would restore trust in the grain market environment. Furthermore, the introduction and re-introduction of export restrictions should be made predictable and transparent. Such a move from discretionary to predictable state interventions would boost the confidence of the private sector in maize marketing.

The Ethiopian government should revisit the export ban policy. In our study, we have shown that, given the current maize price trends, it is not relevant to impose the ban since maize exports are unprofitable. At the current market price, the domestic maize price is wandering between the border prices and it is unprofitable to export maize. Therefore, lifting the export ban, even during normal harvest seasons, would not do any harm to the domestic maize price. As a policy alternative, we recommend that the government should lift the maize export ban, depending on the magnitude of production shocks such as a bumper harvest.

The findings from the regional maize market integration analysis have shown that, despite the renewed conflict in South Sudan, the Addis Ababa maize market is cointegrated with Juba's maize market. Better market integration with regional maize deficit markets would reduce maize price instability in times of bumper harvests in Ethiopia. However, the cross-border trade between Ethiopia with regional deficit markets, such as those in South Sudan and Kenya, faces high risks and transportation costs, making maize exports less profitable for traders. Therefore, there is a need to invest in the road transportation infrastructure that links Ethiopia with potential maize export destinations such as markets in Kenya and South Sudan. Since maize is traded mainly through cross-border trade, better infrastructural development would enable Ethiopia to become a consistent maize exporter to neighbouring eastern African countries. This would improve the competitiveness of maize exports. Public investment in roads can reduce transportation costs and increase maize export parity prices, making maize exports more profitable to private traders.

Estimating behavioural equations using the ECM to account for non-stationarity problems likely comes at the cost of missing the true reflection of the impact of production shocks on the different components of the maize market in Ethiopia. In this study, a price linkage equation could not be introduced because of the excessive zero trade values in the historical data that made it impossible to estimate a trade equation. Henceforth, to ensure that market realities can be captured, future studies could adopt alternative model closures through following synthetic estimation techniques where elasticities are imposed. It will remain a challenge for any large simulation system like a partial equilibrium model to weigh up statistical robustness with a system that captures more of the salient market realities. It is therefore recommended that future studies take a fine balanced approach of imposing statistical robustness as far as data allows, but also ensuring that the modelling system is able to handle market realities.

Appendix

Table 11 Maize import parity price calculation, 2005–2017

Description	Maize import parity (2005–2016)													Outlook period	Scenario 2 (a drought)
	Currency	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2017
US (Gulf)_FOB, Maize (US No 2, Yellow)	$/ton	98	121	163	222	165	185	292	298	260	193	170	159	187	187
Ocean freight (US-Djibouti)	$/ton	42	37	68	70	58	57	48	48	51	52	51	45	45	45
Insurance – 0.3% of FOB	$/ton	0.30	0.36	0.49	0.67	0.50	0.56	0.88	0.89	0.78	0.58	0.51	0.48	0.56	0.56
CIF at Djibouti port	$/ton	141	159	231	293	224	243	340	347	312	246	222	205	233	233
Effective Exchange rate (EER)	ETB/$	10.4	10.5	11	12.5	15.5	19.3	19.5	20.7	21.5	22.7	23.4	24.5	22.9	22.9
CIF at Djibouti port in ETB	ETB/t	1470	1675	2566	3659	3465	4695	6657	7173	6725	5588	5188	5036	5334	5334
Import tariff (5%)	ETB/t	73.5	83.7	128.3	182.9	173.2	234.8	332.8	358.7	336.2	279.4	259.4	251.8	266.7	266.7
Port handling	ETB/t	233	233	233	233	233	233	233	233	233	233	233	233	233	233
Import parity_Djibouti	ETB/t	1777	1992	2928	4075	3871	5163	7222	7765	7294	6100	5681	5521	5834	5834
Distribution costs															
Transport costs from Djibouti port to Addis Ababa (864 km)	ETB/t	380	380	380	437	527	394	431	435	448	447	427	440	440	440
Unloading	ETB/t	32	32	32	32	32	32	32	32	32	32	32	32	32	32
Import parity_Addis Ababa	ETB/t	2189	2404	3340	4544	4430	5589	7685	8232	7774	6579	6140	5993	6306	6306
Addis Ababa_Maize (white)	$/ton	169	169	194	426	288	184	268	281	310	253	223	229	250	250
Addis Ababa_Maize	ETB/t	1760	1782	2152	5333	4452	3557	5247	5802	6674	5751	5203	5616	*5733*	*9201*

Notes: The cost estimates for port handling, inland transport costs, and unloading are based on USAID Bellmon study (USAID, 2010); freight costs are collected from US wheat associates (www.uswheat.org)

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Authors' contributions
MY conceived of the study, participated in the designing of the data collection instruments, collected the data, and performed the statistical analysis. FM and RH provided comments on the draft manuscript. All authors read and approved the final manuscript.

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Availability of data and materials
The datasets used for the study are available from the corresponding author upon request.

Competing interests
The authors declare that they have no competing interests.

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