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Modelling Price Formation and Dynamics in the Ethiopian Maize Market

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ABSTRACT

This study is an attempt to examine price formation, and dynamics in the Ethiopian maize market. A single commodity partial equilibrium and the Johansen's co-integration approaches were used to investigate maize price formation and market integration in the Ethiopian maize market. Findings from the maize industry outlook indicated that maize production is expected to grow for the forecasted period. An increase in maize production was, however, not enough to offset the growth on the demand side. From the yield simulation analysis, we found that a 20% increase in maize yield would reduce nominal maize price by 81%. Co-integration analysis indicated that the Ethiopian wholesale maize markets have become more efficient in the recent years suggesting that price related information is transmitted more efficiently across consumption and production wholesale maize markets.

Keywords: Agricultural market, Equilibrium price, Maize, Market integration, Price formation.

INTRODUCTION

With the recent turmoil in international food market, "getting market prices right" has become an important topic for most governments, including the Ethiopian government. In response to the sharp rise in domestic grain prices of 2007/2008, the Ethiopian government introduced a wide range of policy instruments to tame the soaring domestic food prices. After the reform of market liberalization in March 1990, for the first time the government has become heavily involved in commercial wheat imports. As a form of domestic supply stabilization policy, the Ethiopian government additionally imposed an indefinite export ban on major cereal crops including maize, sorghum, teff and wheat. Generally, it is argued that before embarking on any intervention in domestic grain market, a better understanding of the price formation and possible scenarios of the dynamic grain market environment is crucial for policy makers to make informed decisions for the betterment of producers, investors, traders, and consumers' welfare. Moreover, the dynamic market environment in which producers and consumers operate necessitate a better understanding of price discovery and dynamics of the product they produce. It is against this backdrop that commodity modelling can provide valuable information to assist role players in decision-making.

Several studies have attempted to analyse inter-regional spatial grain market integration in Ethiopia (Negassa *et al.*, 2004; Getnet *et al.*, 2005; Jaleta and Gebremedhin, 2009; Ulimwengu *et al.* 2009; Kelbore, 2013; Tamru, 2013). These studies used different approaches ranging from the primitive correlation analysis to dynamic time series

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model – Ravallion (1986) and Error Correction Model (ECM). The newly introduced approaches - Parity Bounds Model (PBM) and Threshold Autoregressive model (TAR) have also been employed to analyse grain market integration and efficiency in Ethiopia. However, all these studies have emphasised on analysing the co-movement of prices and the efficiency of grain markets in Ethiopia. Knowing whether inter-regional grain markets are integrated or not, provides evidence of price signals transmission across spatial grain markets, but it does not tell us much about price determination, and supply and demand induced grain price instability, which is more useful to policy makers. No attempt has been made so far to explore the fundamentals of supply and demand dynamics, and drivers of equilibrium price in grain market in Ethiopia. This study is therefore an attempt to understand price formation and dynamics in the Ethiopian white maize market. This article also intends to empirically investigate spatial maize market linkages among fifteen wholesale maize market locations in Ethiopia.

The rest of the paper is organised as follows. Section two discusses maize price discovery in Ethiopia. Section three and four explain the data source and the approaches employed in this study. Section five presents the findings obtained from partial equilibrium model and market integration analysis. Section six brings the study to a conclusion.

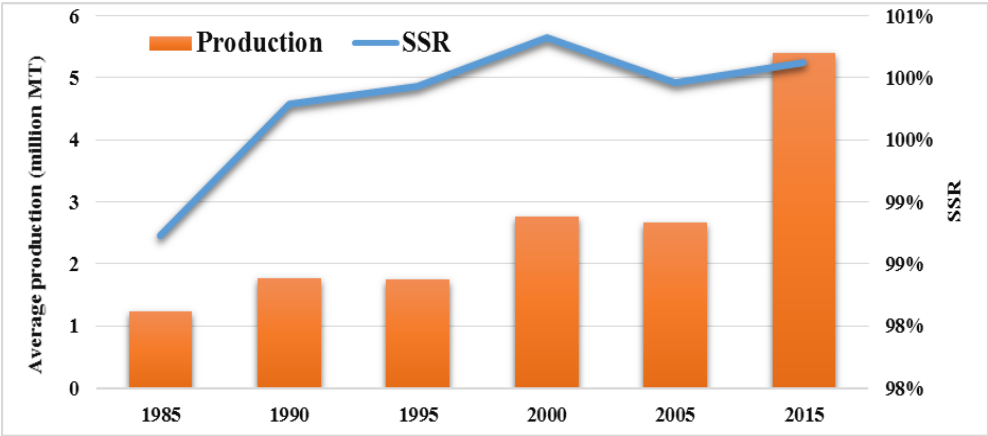
Maize Price Discovery

In order to understand price formation and likely sources of price instability in the Ethiopian white maize market, it is essential to identify the trade regime in which the Ethiopian maize market operates. The trends of maize Self-Sufficiency Ratio (SSR) of Ethiopia indicate that the country has been largely self-sufficient in maize production (Figure 1). The SSR for maize has been fluctuating between 94 and 102% implying that Ethiopia is trading in an autarky trade regime. In autarky trade regime, domestic maize price is expected to be unrelated to international market price shocks. Rather, the dynamics of domestic supply and demand factors apart from government policies are responsible for maize price formation and instability.

MATERIALS AND METHODS

Data Source

This study relied on two different datasets for analysing maize price formation and market integration. The dataset for price formation included producer maize and its



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

Figure 1. Average trends of maize SSR (1980-2015).

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close substitute sorghum prices, rainfall variable, and the different supply and demand components of the Ethiopian white maize balance sheet. Producer price of maize and sorghum commodities were obtained from FAO. Monthly rainfall data were obtained from the National Meteorological Agency of Ethiopia (NMA). The study used rainfall data from eleven surplus maize producing towns from Amhara and Oromia regions. Rainfall data from the Amhara region included Bahir Dar, Gondar, Dembecha, and Debre-Markos towns. While rainfall data from seven maize surplus producing towns of Oromia region, including Arsi-Negele, Bure (Illubabore zone), Bako, Jimma, Nekemete, Meki, and Ziway were included in model estimation. Time series data on maize area harvested, stocks, production, yield, net trade, and trends of maize crop utilisation (feed, seed, and human consumption) were extracted from USDA database. Historical data for the supply and demand components of maize commodity balance sheet range from 2001 to 2015.

While for market integration analysis, the study used the Ethiopian Grain Trade Enterprise (EGTE) monthly wholesale maize market price data. The price dataset was from July 2004 to March 2016 (141 months). It incorporated fifteen wholesale maize market locations in Ethiopia: central market (Addis Ababa Ehel-Berenda market) and regional maize markets (Ambo, Bahir Dar, Dibre-Birhan, Dese, Debre-Markos, Gondar, Hosaena, Jimma, Mek'ele, Nazareth, Nekemete, Shashemene, Woliso, and Ziway). Description of the variables is presented in Annex Table 1.

Table 1 illustrates the mean, maximum, and minimum values of major exogenous and endogenous variables that comprise of the Ethiopian white maize balance sheet. These included maize area harvested, maize yield, maize production, per capita consumption, real producer and wholesale maize and sorghum prices, and population growth.

Econometric Frameworks

To understand maize price formation and effects of government policy interventions on maize price, a partial equilibrium model is developed for the white maize market in Ethiopia. Including the identity and model closure equations, the partial equilibrium model for the Ethiopian white maize commodity incorporates eight individual equations. Several approaches have been employed to estimate behavioural single equations in commodity modelling. The most common approach is Ordinary Least Square (OLS). However, this approach is exposed to the problem of spurious regression in case of non-stationary variables. In an attempt to overcome this misspecification, the study detected the presence of non-stationarity on endogenous and exogenous variables using Augmented Dickey Fuller (ADF) unit root test (Dickey and Fuller, 1979). Hence, the present study

Table 1. Description of endogenous and exogenous variables of maize balance sheet, 2001-2015.

Variables	Units	2001-2006			2007-2011			2012-2015		
		Mean	Max	Min	Mean	Max	Min	Mean	Max	Min
Population	Million	73.51	78.74	68.39	85.34	89.86	80.89	95.77	99.39	92.19
Real maize producer price	ETB $tone^{-1}$	2399	2830	1746	3074	4082	1771	2510	3047	2012
Real wholesale maize price	ETB $tone^{-1}$	2862	3434	1882	3487	4818	2613	2786	3274	2204
Real sorghum producer price	ETB $tone^{-1}$	3149	3727	2374	4136	5233	3017	3097	3734	2366
Real sorghum wholesale price	ETB $tone^{-1}$	4701	5306	3990	5884	7178	4257	4934	5488	4229
Area harvested	1000 ha	1524	1975	1191	1907	2055	1767	2097	2230	1995
Yield	mt ha^{-1}	1.86	2.23	1.50	2.40	2.95	2.12	2.90	3.25	2.35
Production	1000 mt	2848	3776	1788	4602	6069	3750	6070	6580	5050
Human consumption	1000 mt	2477	3085	1626	3838	4899	3175	5103	5443	4536
Per capita maize consumption	kg per capita	33.65	43.11	23.10	44.81	54.52	39.25	53.36	57.57	45.64

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estimated behavioural equations using a combination of the Error Correction Model (ECM) (for non-stationary & co-integrated series) and OLS (for stationary equations). Maize area harvested and ending stocks equations were estimated using Error Correction Model (ECM). Whereas, maize yield and per capita maize consumption equations were estimated using OLS.

After estimating the single behavioural equations, the next step was to estimate the model closure. The choice of closure technique depends on the trade regimes. As illustrated in Figure 1, model closure under autarky trade regime is determined by equating total supply and total demand. Price is thus solved endogenously in the domestic market. Once the behavioural equations are estimated, it is important to make sure that the results are capturing a true reflection of the maize market decision-making behaviour in Ethiopia. One way of checking robustness of model estimation is through model validation techniques. Following Pindyck and Rubinfeld (1991), the following seven statistical techniques namely Mean Average Error (MAE), Mean Average Percentage Error (MAPE), Root Mean Squared Error (RMSE), Theil Inequality Coefficient (U), Bias, Variance, and Covariance proportions were employed to evaluate the forecasting ability of the model.

In addition, this study examined spatial maize market integration among fifteen wholesale maize market locations in Ethiopia. Given the small sample properties and multivariate nature, the Johansen's Maximum Likelihood (ML) method was used to test maize market integration. To illustrate the model specification steps for the Johansen's ML method, suppose that a set of g wholesale maize market prices (g $\geq$ 2) are under consideration that are *I(1)* and co-integrated.

A VAR with *k* lags containing these variables could be set up:

$$y_t = \beta_1 \gamma_{t-1} + \beta_2 \gamma_{t-2} + \cdots + \beta_k \gamma_{t-k} + u_t \quad (1)$$

A Vector Error Correction Model (VECM) of the above VAR (1) form can be specified as follows:

$$\Delta y_t = \Pi\, \gamma_{t-k} + \Gamma_1 \Delta\, \gamma_{t-1} + \Gamma_2 \Delta\, \gamma_{t-2} + \ldots \Gamma_{k-1} \Delta\, \gamma_{t-(k-1)} + u_t \quad (2)$$

where $\Pi = \left(\sum_{i=1}^{k} \beta_i\right) - I_g$ and $\Gamma_i = \left(\sum_{j=1}^{i} \beta_j\right) - I_g$

The test for co-integration between the 'y's is calculated by looking at the rank of the Π matrix. The rank of the Π matrix is equal to the number of non-zero characteristic roots or Eigen values. The Eigen values denoted by λ_i must be positive and less than one in absolute value and are put in ascending order $\lambda_i \geq \lambda_2 \geq \cdots \geq \lambda_g$. If the variables are not co-integrated, the rank of Π will not be significantly different from zero, so $\lambda_i \approx 0\ \forall\ i$. Trace and Max-Eigen test statistics were used to test for the presence of co-integration under the Johansen approach. The test statistics are formulated as:

$$\lambda_{trace}\,(r) = -T \sum_{i=r+1}^{g} \ln(1 - \hat{\lambda}_i), \text{ and} \quad (3)$$

$$\lambda_{max}\,(r, r+1) = -T \ln(1 - \hat{\lambda}_{r+1}) \quad (4)$$

where, r is the number of co-integrating vectors under the null hypothesis and $\hat{\lambda}_i$ is the estimated value for the *i*th ordered Eigen value from the matrix. The test statistics follow non-standard distribution, and the critical values are provided by Johansen and Juselius (1990). If the test statistic is greater than the critical value obtained from the Johansen's table, reject the null of *r* co-integrating vectors in favour of the alternative $r + 1$ (λ_{max}) or more than r for (λ_{trace}). The testing is conduced sequentially under the null, $r = 0, 1, \ldots, g - 1$ (Brooks, 2008).

For 1< rank (Π) <g, there are *r* co-integrating vectors. Π is then defined as the product of the two matrices, α and β, of dimension ($g \times r$) and ($r \times g$), respectively. i.e.

$$\Pi = \alpha\beta' \quad (5)$$

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The matrix β gives the co-integrating vectors, while α is known as the adjustment parameters.

RESULTS AND DISCUSSION

Modelling Maize Price Formation

Area Harvested

Table 2 summarizes the results obtained from the dynamic error correction model by regressing maize acreage on deflated own and substitute crop prices, time trend and rainfall for maize area for the period 2001-2015. Area harvested, sorghum and maize real producer prices were converted to logarithmic value in order to easily interpret values as elasticities.

Estimating the maize supply response using adaptive expectation and partial adjustment models would lead to spurious regression. Alemu et al. (2003) have pointed out that spurious regression and inconsistent and indistinct short-run and long-run elasticity estimates are the major pitfalls of the traditional Nerlovian supply response models. We have made an attempt to estimate a maize acreage model using an Error Correction Model (ECM). ECM overcomes spurious regression problems and give robust estimates of short-run and long-run elasticities.

Table 2. Results for maize supply response.

Variables	Coefficient	Std Error
Short-run elasticities		
Constant	0.043**	0.016
D(RPMAIZEP)	0.062	0.174
D(RPSORGP)	-0.057	0.199
D(RAINL)	0.0004**	0.0002
Error (-1)	-0.205	0.115
Adjusted R^2	0.59	
F-statistics	2.87*	
Long-run supply response		
Constant	897.74	521.87
RPMAIZEP	0.167	0.329
RPSORGP	-0.139	0.268
LNTREND	65.061**	16.662
RAINL	1.128	1.006
Adjusted R^2	0.52	
F-statistics	4.750**	

*, **: Stand for significance at 10 and 5% levels.

We modelled the maize supply response equation using the two-stage approaches proposed by Alemu et al. (2003). First, a static long-run equilibrium regression is estimated. Second, a dynamic error correction model is conducted by including the lagged residual from the static long-run equilibrium regression (of course, the residual from long-run equilibrium regression should be stationary). Findings from the maize supply response suggest that farmers respond very little to price in planning their maize acreage. The estimates of low short-run and long-run price elasticities of supply are comparable with the results that have been obtained by other studies in the field of supply response in Ethiopia and elsewhere in smallholder farmers' responsiveness to market incentives (Alemu et al., 2003; Tripathi, 2008). The low price elasticities of supply can be attributed to structural constraints that have limited farmers in making informed adjustment to market incentives. The land tenure system also contributes to the low magnitude of agricultural supply response in Ethiopia. In Ethiopia, land belongs to the state and farmers cannot lease it or get it from other farmers. As a result, farmers continue to practice farming within their small landholding sizes, with little or no prospects for acquiring additional land or for expanding their cultivation. The other reason for low supply response is the subsistence nature of maize farming practices in Ethiopia. Maize is mainly produced for household consumption (> 75%). Only 13% of maize production is marketed (CSA, 2011).

Furthermore, we also noticed that non-price factors such as rainfall and technological progress captured by the trend variable are more important determinants in the maize supply response than price-related factors are. Hence, from this analysis, it can

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be inferred that price is not a significant factor in influencing the maize acreage decision. Rather, the analysis confirms that rainfall and technological progress are relatively more important for higher maize acreage growth.

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. In the yield equation, the trend variable appeared with the expected positive sign and it was statistically significant at 5% significance level (Table 3). Technological introduction or progress on maize commodity over the years has positively contributed to maize yield improvement in Ethiopia. Henceforth, Ethiopia has registered tremendous growth in boosting maize yield. The five years average maize yield between 2011 and 2015 was estimated at 2.94 tons ha^{-1} (USDA, 2015). Maize yield reached a peak level of 3.25 tons ha^{-1} in 2013. South Africa and Ethiopia are the only countries in Sub Saharan Africa (SSA) that have attained > 3 tons ha^{-1} on maize yield. Only Zambia and Uganda have managed to reach > 2.5 tons ha^{-1}, followed by Malawi with > 2 tons ha^{-1}. Ethiopia is ranked fifth in terms of area devoted for maize production in SSA, but is second only to South Africa in yield and third after South Africa and Nigeria in production (Abate *et al*., 2015).

Per Capita Consumption

Per capita maize consumption was modelled as a function of own price, price of substitutable crop (i.e. sorghum), real per capita GDP, two shift variables capturing the soaring food price phenomena and change in the policy environment from free trade to export ban. A trend variable was also incorporated to examine the changing trend in the consumption habits of maize consumers over time.

Table 3. Results for maize yield equation.

Variables	(1) Robust OLS[a]	(2) Elasticity
IRRIG	0.308	0.003
	(28.14)	
SEED	0.381	0.038
	(1.059)	
LNTREND	0.460**	0.369
	(0.191)	
RAINP[b]	0.0035	1.65
	(NA)	
Constant	2.336*	
	(1.110)	
Observations	15	
Adjusted R^2	0.61	
F-statistics	6.49**	

[a] Robust standard errors in parentheses; ** $P< 0.05$, * $P< 0.1$. [b] No standard errors are reported for the rainfall variable. Because of undesirable coefficient signs, we modified the value of 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 in rainfall, the use of 1.65 elasticity value is reasonable.

All the estimated variables in the per capita white maize consumption have the expected signs. Income elasticity indicated that maize is a normal good in Ethiopia: higher income raises consumption. 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 urbanisation, people tend to move away from the consumption of root crops and coarse grains to wheat and rice. However, 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 stable food crop.

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

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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. The experiences of other countries on the effects of export bans on domestic prices are mixed. Diao *et al*. (2013) found that the maize export ban in Tanzania reduced maize producer prices by 9 to 19%. In contrast, Porteous (2012) and Chapoto and Jayne (2009) found no significant relationship between an export ban and domestic prices. The authors argue that in most countries, export bans are implemented in response to soaring domestic grain prices. Unless the prices in other trading partner countries rise much faster, the higher domestic prices are likely to make exports unprofitable and the ban unnecessary.

Ending Stocks

Ending stocks was modelled as a function of beginning stocks, maize production, real wholesale maize price and wheat food aid. With the exception of real wholesale maize price, the estimated variables in the ending stock equation were consistent with our expectations (Table 5). As opposed to our expectation and economic theory, real wholesale maize price was positive in the original ECM model. This means that as the wholesale prices increase, traders would sell maize production to the EGTE. This is not realistic because when wholesale prices increase traders become reluctant to sell to the EGTE. Instead, they tend to sell to open markets at higher price. To overcome this difficulty, a calibration technique was employed to arrive at the expected negative sign.

Table 4. Results for per capita maize consumption.

Variables	(1) Robust OLS[a]	(2) Elasticity
RMPRICE	-0.0045	-0.322
	(0.008)	
RPCGDP	0.117	0.012
	(0.167)	
RSORGPRICE	0.007	0.074
	(0.008)	
SHIFT05	11.12*	
	(5.592)	
SHIFT2011	14.65*	
TREND	-2.894	-0.0071
	(3.867)	
Constant	6.720	
	(22.567)	
Observations	15	
Adjusted R^2	0.64	
F-statistics	5.086**	

[a] Robust standard errors in parentheses; ** $P<0.05$, * $P<0.1$.

Model Performance

The reported forecast statistics value indicates that most of the forecast accuracy statistics using Theil's Inequality Coefficient (U) produced results closer to zero, which is

Table 5. Estimated results for ending stocks.

Variables	(1) ECM [a]	(2) Elasticity
D (MPROD)	0.0952	1.04
	(1.624)	
D (RMPRICE)[b]	-0.0397	
	(NA)	-1.2
D (BSTOCK)	0.310	
	(1.083)	0.319
D (AID)	-0.096	
	(-0.954)	-0.139
ECT (-1)	-	
	1.345**	
Constant	2.672	
	(0.059)	
Observations	14	
Adjusted R^2	0.45	
F-statistics	3.095*	

[a] Robust standard errors in parentheses; ** $P<0.05$, * $P<0.1$.
[b] No standard errors are reported for the real whole sale maize price. The reported value is a calibrated coefficient value using a hypothetical elasticity value of -1.2

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an indication for good model forecast (Table 6). In addition, except ending stocks equation, the mean absolute percentage error is around and below ten percent for the remaining models. Hence, we can conclude that the single behavioural models perform reasonably well in tracking the actual values, and therefore can be used for forecasting and policy analysis.

Maize Market Outlooks and Simulation Results

This section illustrates the findings from the maize market outlooks and simulation analysis based on status quo assumption of policy variables. The simulation period is from 2017-2025. In order to examine the maize industry outlooks from 2016-2025, the exogenous variables were forecasted. Whereas the forecasted values for the main macroeconomic variables such as Consumer Price Index (CPI) and population growth rate were obtained from the projection made by the International Monetary Fund (IMF) and the World Bank.

Maize Market Outlooks

Maize production is expected to grow for the forecasted period from 2016-2025. Production is expected to reach 8.7 million tons by 2025. The average maize production during the forecasted period is 7.7 million tons. This represents an increase of 81% over the fifteen years average of 4.29 million tons during 2001-2015. The increase in maize production during the forecasted period is mainly driven by the expansion in maize area harvested than yield improvement. Maize area harvested is projected to increase by 46% from 1.8 million ha from 2001-2015 to 2.6 million ha for the forecasted period of 2016-2025. On the other hand, maize yield is expected to rise by 26% from the fifteen years average of 2.3 to 2.9 tons ha^{-1} for the forecasted period.

The increase in maize production during the baseline period is, however, not enough to offset the growth on the demand side. On average, human consumption is expected to reach 6.7 million tons during the forecasted period. This has shown an increase by 85% over the fifteen years period of 3.6 million tons from 2001-2015. *Per capita* maize consumption is expected to reach 62.3 kg $capita^{-1}$ in 2025. The average projected *per capita* consumption from 2016-2025 is 59.3 kg $person^{-1}$, which is 39% higher than the average per capita maize consumption of 42.63 kg $person^{-1}$of 2001-2015.

Impact of Maize Yield Shock

Suppose that the introduction of technological innovation (a new maize variety or conservation farming) raises maize farmers' yield by 20%. The shock was introduced in 2017 baseline period. How does this increase in yield change maize price? Does yield improvement make maize consumption better off or worse than it was before? In this section, we shall address these questions by comparing the

Table 6. Forecast evaluation for the estimated single equation models.

Forecast statistics	Behavioral equations			
	Area harvested	Per capita consumption	Yield	Ending stocks
Theil inequality coefficient (U)	0.0484	0.0513	0.058	0.1524
Bias Proportion	0.000	0.000	0.00	0.0027
Variance proportion	0.105	0.0581	0.081	0.248
Covariance proportion	0.895	0.9419	0.919	0.749
Mean Absolute Percentage Error (MAPE)	7.288	8.6465	10.326	32.297
Mean Absolute Error (MAE)	121.11	3.1784	0.2307	124.087
Root Mean Squared Error(RMSE)	176.64	4.4799	0.273	145.05

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simulation results with the baseline values. We answer the question about the impact of maize yield simulation in three steps. Primarily, we examine the short-run and long-run response of the different components of the maize market model. Then, we consider the direction and proportion of the shift. In the end, we quantify how these dynamic changes in the supply and demand components translate into the maize market equilibrium price.

The dynamic responses of the maize sub-sector for a bumper harvest are summarised in Table 7. From the yield simulation analysis, it is clear that a 20% increase in maize yield would result in an increase in maize production by 20%. The impact of yield simulation is more pronounced and persistent on maize ending stocks and nominal maize price. As compared to the baseline, a 20% increase in maize yield could reduce nominal maize price substantially by 81%. In the short-run (within the year), a positive change in yield would increase maize ending stocks by 87%, and the effect will also continue in the long-run. A 20% 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% change in maize yield could increase domestic maize use by 14%. Harvested maize area has remained unaffected by a

Table 7. Yield simulation and percentage increase compared to the baseline.

Affected components	2017	2018	2019	2020	2021	2022	2023	2024	2025
Maize yield					tons ha^{-1}				
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^{-1}				
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 outcomes.

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20% positive change in maize yield.

Long-run Relationships

This section examines the spatial maize market integration among fifteen wholesale maize markets in Ethiopia. Wholesale maize markets are selected based on their representativeness of crop production, consumption areas, importance to the national grain trade flow and data availability. The descriptive results for the wholesale maize prices are presented in Table 8.

Since all the price series are non-stationary and integrated of the same order I(1), co-integration analysis is therefore appropriate to investigate the long-run relation among maize market prices. Given the large number of maize markets, co-integration tests are conducted in a pairwise fashion. Following the results of Toda and Yamamoto (1995) causality test. Addis Ababa maize market is treated as an exogenous maize market. Thus, in the subsequent co-integration analysis, regional wholesale maize markets are paired with Addis Ababa maize market. The use of Addis Ababa maize price as a central market is appropriate to this study because with 15 maize markets, there are 105 [$(n^2-n)/2$] possible market pairs.

Co-integration among maize market pairs is tested using Johansen's method (Johansen 1991). The results for the co-integrated maize market pairs are presented in Table 9. Trace and Maximal Eigen value test statistics provided no conflicting results. In both cases, the null of zero co-integrating vectors (r= 0) was rejected. The last column in table 9 presents the lag length selected for long-run analysis of market pairs. Optimum lags were chosen using the information criterion [Akaike Information Criterion (AIC), Schwarz Bayesian Criterion (SBC), and Likelihood Ratio (LR)].

Results from Johansen co-integration tests show that no co-integration was found between Addis Ababa with regional maize markets of Debre-Markos, Hosaena, Shashemene, and Nazareth market pairs. Given the proximity of Nazareth and Addis Ababa, the absence of co-integration between the two wholesale maize markets was not expected. One possible cause for the absence of co-integration between Nazareth and Addis Ababa maize market could be the

Table 8. Descriptive results of the nominal wholesale maize market prices, July 2004 to March 2016 (ETB [a] 100 kg^{-1}).

Markets	Mean	Std. Dev.	Max	Min	Driving distance from Addis Ababa (km)	Market type
Addis Ababa	347.46	157.28	631	123	-	Surplus
Ambo	330.38	154.85	696	110	119	Surplus
Bahir Dar	343.93	169.82	770	112	552	Surplus
Debre-Birhan	356.44	164.87	663	123	132	Surplus
DM [b]	361.74	180.87	774	116	306	Surplus
Gondar	370.40	171.10	791	141	732	Surplus
Hosaena	376.68	182.01	801	127	228	Surplus
Jimma	316.61	157.59	718	100	352	Surplus
Nazareth	348.92	163.31	680	120	86.5	Surplus
Nekemete	312.28	155.94	635	96	318	Surplus
Shashemene	358.01	180.97	770	107	251	Surplus
Woliso	344.57	162.63	718	107	111	Surplus
Ziway	345.43	167.69	718	106	163	Surplus
Dese	358.07	160.01	690	129	388	Deficit
Mek'ele	385.17	179.46	904	99	762	Deficit

[a] Using the exchange rate of 13 May 2016, 1 Ethiopian Birr (ETB) was trading at around 0.046 USD.
[b] Denotes Debre-Markos.

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Table 9. Johansen tests for co-integration between wholesale maize market prices[1].

Markets	Trace Ho	Trace statistic	Max Ho	Max-Eigen statistic	Lags
Addis-Ambo	$r = 0$	29.08***	$r = 0$	29.00***	2
	$r \leq 1$	0.075	$r = 1$	0.075	
Addis-BD[a]	$r = 0$	23.81***	$r = 0$	20.09**	2
	$r \leq 1$	3.72	$r = 1$	3.72	
Addis-DB[a]	$r = 0$	19.74***	$r = 0$	19.64***	3
	$r \leq 1$	0.10	$r = 1$	0.10	
Addis-Dese	$r = 0$	25.29***	$r = 0$	25.20***	2
	$r \leq 1$	0.09	$r = 1$	0.09	
Addis-Gondar	$r = 0$	20.38***	$r = 0$	20.37***	2
	$r \leq 1$	0.008	$r = 1$	0.009	
Addis-Jimma	$r = 0$	18.53***	$r = 0$	18.47***	9
	$r \leq 1$	0.06	$r = 1$	0.06	
Addis-Mek'ele	$r = 0$	13.71**	$r = 0$	13.71**	3
	$r \leq 1$	0.003	$r = 1$	0.003	
Addis-Nekemete	$r = 0$	22.44**	$r = 0$	18.87**	8
	$r \leq 1$	3.57	$r = 1$	3.57	
Addis-Woliso	$r = 0$	35.06***	$r = 0$	34.91***	2
	$r \leq 1$	0.15	$r = 1$	0.15	
Addis-Ziway	$r = 0$	27.01***	$r = 0$	26.87***	2
	$r \leq 1$	0.15	$r = 1$	0.15	

[a] BD and DB stand for Bahir Dar and Debre-Birhan markets. ***, **: Significance levels at 1 and 5%.

presence of structural breaks, which may lead to misleading inference on co-integration results. It is widely accepted that the presence of structural breaks distorts the validity of conventional unit root and co-integration tests (Phillips, 1986; Perron, 1989). Therefore, tracing out the presence of breaks in our data series is crucial, especially in the presence of commodity price crisis of 2008 and 2011. Furthermore, since 2008, the Ethiopian government intervened in domestic grain market in response to high domestic commodity prices. Hence, ignoring structural break test in volatile commodity market environment and with the presence of government interventions in agricultural market might falsely lead to non-rejection of the null hypothesis of no co-integration.

The Bai and Perron (1998) breakpoint test is used to analyse the effects of structural breaks on maize markets integration. The Bai and Perron (1998) structural break test is useful to test unknown breaks in the price series. The test uses the full sample and adopts a different dummy variable for each break. We further tested the presence of co-integration by accounting the identified structural breaks using the Stock and Watson's (1993) Dynamic Ordinary Least Square approach (DOLS). The Johansen method, being a full information technique, is exposed to the problem that parameter estimates in one equation are affected by any misspecification in other equations (Azzam & Hawdon, 1999:7). In contrast, the Stock and Watson method is a robust single equation approach, which overcomes the simultaneity bias by incorporating leads and lags of first differences of the regressors, and for serially correlated errors by a Generalized Least Squares (GLS) procedure. For the sake of brevity, the mathematical specifications and results for the Bai and Perron (1998) breakpoint and DOLS tests are not presented here. Interested readers can refer to Rafailidis and Katrakilidis (2014) to get a detailed explanation in these two approaches.

Indeed, the conclusion for co-integration tests altered when breakpoints were considered in the analysis. Analysing co-

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integration by taking into account breaks gives a different story for maize markets considered as non- cointegrated in Johansen's approach (see annex Tables 2-3). Regional maize markets (Shashemene, Nazareth, Debre-Markos, and Hosaena) found to have no co-integration with Addis Ababa maize market which became co-integrated when structural breaks were taken into account.

CONCLUSIONS

This study is an attempt to examine price formation and dynamics in the Ethiopian maize market. Results from the Johansen tests reveal that out of 14 maize market pairs, long-run relationship is confirmed in 11 market pairs. Nevertheless, the conclusion for co-integration tests altered when breakpoints were considered in the analysis. When structural breaks were considered in the price series, all regional maize market pairs became co-integrated with the central Addis Ababa maize market. Co-integration of all maize market pairs considered in this study is a reflection of better spatial maize market linkages in Ethiopia after the introduction of a Structural Adjustment Program (SAP).

Findings from price formation demonstrate that technological progress on maize commodity has increased maize yield in Ethiopia. As a result, maize production has improved considerably. As demonstrated in the yield simulation result, a 20% increase in maize yield would increase maize production by 20% and could reduce maize price substantially by 81%. This may create disincentives for producers. Thus any interventions in the input sector should go hand in hand with market development. Given the imposition of an export ban on maize, the only available market for farmers and traders is the domestic market. The domestic maize market outlet is also confronted with many challenges. The major challenge is the low maize demand in urban areas. In spite of maize being the cheapest source of calorie, consumption of processed maize is not common in Ethiopia. As a result, millers have allotted much of their processing capacity to wheat flour and products than maize flour. As explained by (RATES, 2003), maize represents only 4% of the total milling capacity in Ethiopia. The challenge for expansion of maize processing industry is the low demand in urban areas, where the purchasing power is relatively better. In such a situation, involvement in maize processing industry is not feasible for investors. In addition, the use of maize grain and residue for poultry and livestock production has not been widely practiced in Ethiopia. Despite having the largest livestock population in Africa, the use of maize residues for silage making at smallholder and industrial level is very limited in Ethiopia. Therefore, expansion of the industrial use of maize is an advisable policy option. Governments could take steps in enticing private sectors and small-scale enterprises to take part in the sector, by providing credit and infrastructure services. Furthermore, linking private processors with potential processed food buyers such as the Purchase for Progress Program (P4P) of the World Food Program (WFP) and productive safety net programmes is a step in the right direction. Thus, the output from private processors will be channelled to food insecure or drought prone areas of Ethiopia either for a relief or food for work initiatives.

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مدل سازی شکل گیری و پویایی قیمت در بازار ذرت اتیوپی

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چکیده

هدف این مطالعه بررسی شکل گیری و پویایی قیمت در بازار ذرت اتیوپی است. تعادل جزئی یک کالا و روشهای همگام سازی یوهانسن (the Johansen's co-integration approaches) برای بررسی شکل گیری قیمت ذرت و ادغام بازار در فروش ذرت اتیوپی مورد استفاده قرار گرفت. یافته های صنعت ذرت نشان میدهد که انتظار می‌رود تولید ذرت طی دوره پیش بینی شده، افزایش یابد. اگرچه افزایش تولید ذرت، برای جبران نیاز و تقاضای در حال رشد کافی نبوده است. از تجزیه و تحلیل شبیه سازی عملکرد، مشخص شد که ۲۰٪ افزایش در عملکرد ذرت می تواند منجر به کاهش ۸۱ درصدی قیمت اسمی ذرت شود. تجزیه و تحلیل هم انباشتگی نشان داد که بازارهای عمده فروشی ذرت اتیوپی در سال های اخیر کارایی بیشتری داشته اند که نشان گر انتقال بیشتر و بهتر اطلاعات مرتبط با قیمت در بازار مصرف و تولید عمده محصولات ذرت می باشد.

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