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Abstract

In response to the sharp rise in domestic grain prices of 2008, the Ethiopian government introduced a wide range of policy instruments to tame the soaring domestic food prices. It is generally argued that before embarking on any intervention in domestic grain market, better understanding of price formation and possible scenarios of the dynamic grain market environment is crucial for policymakers to make informed decisions. This study aimed at examining the price formation and dynamics in the Ethiopian maize market. Furthermore, this article empirically investigate spatial maize market linkages and test maize price leadership role in order to understand as to whether or not there is a central maize market that dictate and lead price information flow over regional maize markets in Ethiopia.

Keywords: Grain market; price shocks; maize; market integration; price formation

1. INTRODUCTION

Recently, the Ethiopian grain markets have been characterised by price spikes. The year on year change in food price inflation reached all-time high level of 60% in 2008 (FAO, 2015). Compared to other major crops, maize commodity prices have historically been more volatile. For instance, maize prices collapsed considerably whenever there are bumper harvests as was the case in 1995/96, 1996/97, 1999/00, and 2001/02 (RATES, 2003). Maize prices collapsed by almost 80% and reached the lowest in early 2002. Bumper harvests led to the significant price drop and created market glut in higher producing areas. Accordingly, the low market price created disincentive effects for farmers to use improved production technologies such as commercial fertilizer and improved seed. Compared to 2002, maize production dropped by 14% and 3% during 2003 and 2004 (FAO, 2015). The lesson learned by government as well as international and national research organizations with regards to the unprecedented low maize price episode of 2002 was that crop productivity improvement alone does not translate into welfare gains of producers. Therefore, agricultural policies that target farmers' livelihood improvement through technology adoption and crop productivity should go hand in hand with market development.

Since 2007, maize prices have shown an upward trend in domestic grain market. The domestic prices of maize reached close to US$ 350/ton by mid-2009. The recent persistence of high maize prices in the presence of remarkable growth in domestic maize production and supply remains a puzzle. Maize production has almost doubled (88%) in Ethiopia since 2004 (USDA, 2015). Despite the price volatility, maize is still continues to be a strategic crop to Ethiopia's food security interest.

With the recent turmoil in international food market, "getting market prices right" has become an important topic for most governments. This is also the case for the Ethiopian government. In response to the sharp rise in domestic grain prices of 2008, the Ethiopian government introduced a wide range of policy instruments to tame the soaring domestic food prices. After the adoption of market liberalisation, the government for the first time has become heavily involved in commercial wheat imports. As means of domestic supply stabilisation, the Ethiopian government has also imposed an indefinite export ban on major cereal crops including maize, sorghum, teff and wheat. It is generally argued that before embarking on any intervention in domestic grain market, 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. The dynamic market environment in which producers and consumers operate necessitate 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 model – Ravallion (1979) and Error Correction Model (ECM). Newly introduced approaches - Parity Bounds Model (PBM) and Threshold Autoregressive model (TAR) have also employed to analyse grain market integration and efficiency in Ethiopia. However, all these studies have emphasised on analysing the co-movement of prices and efficiency of grain markets in Ethiopia. While knowing whether inter-regional grain markets are integrated or not provides evidence of price signals transmission across spatial grain markets, 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 so far been made 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 discovery in the Ethiopian maize market. This article also intends to empirically investigate spatial maize market linkages and test maize price leadership in order to understand as to whether or not there is a central maize market that dictate and lead price information flow over regional maize markets in Ethiopia. Understanding the existence of a central market will make it easier for policymakers to monitor and intervene price distortion in grain market. Thus, further reducing the costs of price stabilisation policy.

The rest of the paper is organised as follows. Section two discusses maize price discovery in Ethiopia. Section three describes the approaches and data sources of the study. Section four presents the findings obtained from partial equilibrium model, market integration, and price leadership analysis. Section five concludes.

2. MAIZE PRICE DISCOVERY

In order to understand price formation and likely sources of price instability in the Ethiopian maize market, it is essential to identify the trade regime where the Ethiopian maize market operates. The trends of maize Self-Sufficiency Ratio (SSR) of Ethiopia indicates that the country has been largely self-sufficient in maize production (Figure 1). The SSR for maize has fluctuated between 94% and 102% implying that Ethiopia is trading in 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.

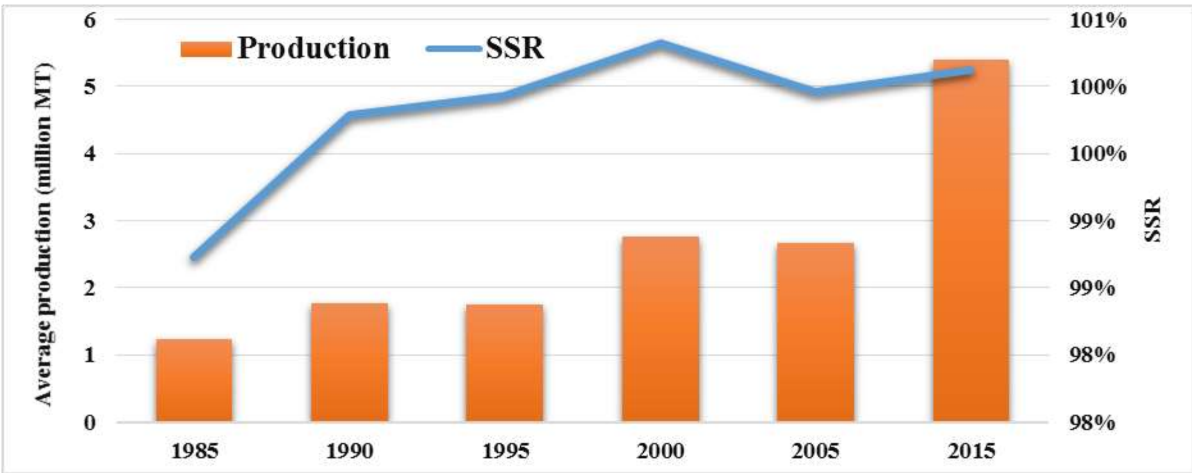

Figure 1. Average trends of maize SSR, (1980-2015)
Source: Author's calculation using USDA data (2015)

3. METHOD OF ANALYSIS

3.1 Data source

The study relied on data obtained from different sources including FAO, USDA, Central Statistical Agency of Ethiopia (CSA), Ethiopian Grain Trade Enterprise (EGTE), and National Meteorological Agency of Ethiopia (NMA). Time series data on producer prices of maize commodity are obtained from FAO. While, the study uses EGTE monthly wholesale maize market price data. The price dataset incorporate 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). The price series are from July 2004 to March 2016 (141 months).

Monthly and annual rainfall data are obtained from NMA. Rainfall data from eleven surplus maize producing towns from Amhara and Oromia regions were used. From the Amhara region, rainfall data from Bahir Dar, Gondar, Dembecha, Debre-Markos, and Bure towns were used. In addition, rainfall data from six maize surplus producing towns of the Oromia region, including Arsi-Negele, Bako, Jimma, Nekemete, Shashemene, and Meki-Ziway were included in model estimation. Time series data for a partial equilibrium model on area harvested, stocks, production, yield, net trade, trends of maize crop utilization (feed, seed and household consumption) are extracted from USDA database. The historical data for the supply and demand components of maize commodity range from 2000 to 2015.

3.2 Econometric frameworks

A partial equilibrium model was estimated to understand price formation and equilibrium pricing in the Ethiopian maize market. Generally, the structure of the model is based on the concept of supply and demand interaction, trade flows and prices. Maize market price formation has three blocks consisting of supply and demand blocks and model closure. Including the identity and model closure, the partial equilibrium model for the Ethiopian maize commodity incorporates seven individual equations. Equations for area harvested, yield, per capita maize consumptions and ending stocks were estimated using Ordinary Least Square (OLS). Moreover, this study examines spatial wholesale maize market integration and test price leadership among fifteen wholesale maize market locations in Ethiopia. Given the small sample properties and multivariate nature, the Johansen's Maximum Likelihood (ML) method (1991) is used to test spatial 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 ≥ 2) are under consideration that are I(1) and which are thought to be cointegrated. 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 $\Gamma_i = \left(\sum_{j=1}^{i} \beta_j\right) - I_g$

Cointegration test between the y's is calculated by looking at the rank of the Π matrix. Trace and Maximal Eigenvalue test statistics are used to test for the presence of cointegration under the Johansen approach.

Furthermore, Toda and Yamamoto (1995) (From now on T-Y) Granger Causality approach is used to test a central maize market hypothesis. The novelty of T-Y approach is that unlike the conventional Granger Causality test, the researcher does not bother for the order of integration and cointegration. You can estimate the VAR in level form and evaluate the relationships among variables using the modified Wald (MWALD) test.

4. RESULTS AND DISCUSSION

4.1 Modelling maize price formation

4.1.1 Area harvested

Area harvested for maize was assumed to be impacted by lagged own price, lagged price of substitutable crop, lagged area of maize planted, rainfall and market incentives. Maize and wheat are substitutable staple food crops. As a result, maize land allocation is expected to depend on the previous year wheat market price. A shift variable from 2004 was used to examine whether the prevailing higher domestic commodity price has encouraged farmers to allocate more land for maize production. It is a measure of the supply responsiveness of farmers to market incentives.

Results for maize area harvested equation are illustrated in Table 1. The findings reveal that maize land allocation is inelastic to market incentives. The elasticity for lagged maize producer price and maize price pattern since 2004 were 0.035 and 0.22, respectively. The results confirm the fact that the decision to plant maize is more sensitive to lagged maize area allocation than market price patterns. This result makes sense when considering the low market oriented nature of maize production in Ethiopia. Majority of maize production is retained for household consumption and seed (85%). Only 12% of maize output is marketed (CSA, 2011). Maize price volatility may also have a role for the low supply responsiveness of maize to market incentives.

Table 1: Results for maize area harvested equation

Variables	(1) Robust OLS	(2) Elasticity
RPMAIZEP_L	0.0864	0.0348
	(1.724)	(0.69)
RPWHEATP_L	-0.437	-0.286
	(1.471)	(0.96)
AREA_L	0.416	0.408
	(0.243)	(0.241)
SHIFT2004	478.3	0.2211
	(311.5)	(0.146)
RAINL	-3.956	-0.2225
	(2.777)	(0.151)
Constant	1,545	
	(1,042)	
R^2	0.757	

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

4.1.2 Yield

Maize yield equation was estimated as a function of rainfall, maize area under irrigation, improved seed utilization and technological improvement over time. The results for the yield equation are reported in table 2. The yield results reveal that the trend variable appeared with the expected positive sign and was statistically significant at 5%. Technological introduction on maize commodity over the years has, thus, positively contributed to maize yield improvement in Ethiopia. Within one and a half decades, the country has managed to boost its maize yield by about 50%. The current five years average maize yield is estimated at 2.75 tons/ha. Maize yield reached a peak level of 3.1 tons/ha in 2012. South Africa and Ethiopia are the only countries in Sub Saharan Africa (SSA) that have attained >3 tons/ha on maize yield. Only Zambia and Uganda have managed to reach >2.5 tons/ha, followed by Malawi with > 2 tons/ha. At present, 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).

Table 2: Results for maize yield equation

Variables	(1) **Robust OLS**	**(2) Elasticity**
IRRIG	22.42	0.224
	(26.99)	(0.267)
SEED	0.3923	0.374
	(0.852)	(0.082)
LNTREND	0.605**	0.481
	(1.858)	(0.144)
RAIN	-0.0002353	-0.095
	(0.00063)	(0.254)
Constant	0.798	
	(0.935)	
R^2	0.776	

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

4.1.3 Per capita maize consumption

The findings for drivers of *per capita* maize consumption in Ethiopia are illustrated in Table 3. *Per capita* maize consumption is modelled as a function of own price, price of substitutable crop, 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 is also incorporated to examine the changing trend in the consumption habits of maize consumers over time. The elasticity coefficient on real wheat price indicates that wheat is not a perfect substitute for maize. A 10% increase in wheat price increases the *per capita* maize consumption by 0.9%. Thus, maize consumption is inelastic to changes in wheat price. Given the considerable price difference between the two crops, this finding is reasonable. Wheat price is, on average, twofold higher than maize prices, which makes it even harder for consumers to switch to wheat consumption for a small increase in maize prices.

Table 3: Estimated results for per capita maize consumption

Variables	(1) **Robust OLS**	(2) **Elasticity**
RPCGDP	0.102	0.5
	(0.238)	(1.142)
RPMAIZE	-0.015	-0.3
	(0.0087)	(0.118)
RWHEAT	0.00287	0.092
	(0.0079)	(0.253)
SHIFT2004	4.475	0.083
	(7.402)	(0.138)
SHIFT2011	3.807	0.026
	(3.006)	(0.02)
TREND	2.261	0.4
Constant	-23.43	
	(28.14)	
R^2	0.876	

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

4.1.4 Ending stocks

Ending stocks is modelled as a function of beginning stocks (lagged ending stock), maize production and the prevailing wholesale maize price. The estimated variables in the ending stock equation are consistent with our expectations (Table 4). Maize production was positive and significant at 5% significance level. Ending stock is highly elastic for maize production. A 10% increase in maize production raises maize ending stocks by 15.6%. The Ethiopian Grain Trade Enterprise (EGTE) is the only parastatal organization involving in the procurement of maize from farmers for three purposes; the national food reserve, school feeding, and the Productive Safety Net Programme (PSNP).

Table 4: Estimated results for ending stocks

Variables	(1) **Robust OLS**	(2) **Elasticity**
MPPROD	0.207**	1.56
	(0.056)	(0.441)
RPMAIZE	-0.489	-0.74
	(0.524)	(0.832)
BEGINNING	0.286	0.255
	(0.177)	(0.163)
Constant	-44.13	
	(516.74)	
R^2	0.822	

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

4.2 Maize outlook and simulation results

The sections below discuss the baseline projection for maize industry from 2015-2020 based on status quo assumption of policy variables and forecast of exogenous variables.

4.2.1 Maize outlooks

Maize production is expected to be stagnant for the forecasted period from 2015-2020. Production is expected to reach 6.6 million tons by 2020.This represents an increase of 32% over the ten years period of 2005-2014. This production increase is, however, not enough to offset the increase in demand. Maize consumption is projected to increase by 10% and 5% in 2016 and 2017, respectively. Total domestic use (consumption and seed) is expected to reach its peak annual growth of 8% in 2016 and will slow down in the subsequent years. *Per capita* maize consumption is expected to reach 50.5 kg/capita in 2020. The average projected *per capita* consumption from 2015-2020 is 50 kg/person, which is 7% higher than the average per capita maize consumption of the past ten years (2005-2014).

4.2.2 Maize yield shock simulation

Suppose that the introduction of technological innovation (new improved variety or conservation farming) raises maize farmers' yield by 10%. How would this increase in yield affect maize price? Does yield improvement make maize consumption better off or worse off than it was before? In this section, we will address these questions by comparing the simulation results with the baseline values. The results of these scenarios are summarized in Table 5. A 10% increase in maize yield in 2016 will result in an increases in maize production. Higher maize production will substantially reduce the nominal wholesale maize prices by 44% in 2016 in comparison to the baseline. The low market price coupled with high production increases maize ending stocks by 20%. Compared to the baseline, the domestic maize use increases moderately by 6%.

Affected components	2016	2017	2018	2019	2020
Maize Yield	**Ton/hectare**				

Table 5: Maize yield simulation and percentage increase compared to the baseline

	Baseline	**2.80**	**2.84**	**2.88**	**2.90**	**2.92**
	Scenario	**3.08**	**2.84**	**2.88**	**2.90**	**2.92**
	Absolute change	**0.28**	**0.00**	**0.00**	**0.00**	**0.00**
	% Change	**10%**	**0%**	**0%**	**0%**	**0%**
Total Maize Production		**Thousand tonnes**				
	Baseline	**6532.77**	**6557.42**	**6583.7**	**6597.75**	**6634.74**
	Scenario	**7186.05**	**6557.42**	**6583.7**	**6597.75**	**6634.74**
	Absolute change	**653.28**	**0.00**	**0.00**	**0.00**	**0.00**
	% Change	**10%**	**0%**	**0%**	**0%**	**0%**
Domestic Maize Use		**Thousand tonnes**				
	Baseline	**6314.72**	**6579.81**	**6711.3**	**6778.54**	**6829.09**
	Scenario	**6704.31**	**6722.15**	**6777.14**	**6808.81**	**6842.93**
	Absolute change	**389.58**	**142.34**	**65.84**	**30.27**	**13.84**
	% Change	**6%**	**2%**	**1%**	**0%**	**0%**
Maize Ending stock		**Thousand tonnes**				
	Baseline	**1334.92**	**1312.53**	**1185**	**1004.17**	**809.807**
	Scenario	**1598.61**	**1433.88**	**1240.47**	**1029.41**	**821.22**
	Absolute change	**263.69**	**121.35**	**55.51**	**25.24**	**11.42**
	% Change	**20%**	**9%**	**5%**	**3%**	**1%**
Nominal Wholesale Maize Price		**ETB/ton**				
	Baseline	**4413.72**	**6137.31**	**8659.20**	**11795.20**	**15273.5**
	Scenario	**2476.29**	**5400.31**	**8305.38**	**11626.83**	**15193.98**
	Absolute change	**-1937.42**	**737.00**	**353.80**	**-168.33**	**-79.49**
	% Change	**-44%**	**-12%**	**-4%**	**-1%**	**-1%**

Source: Model output

4.3. Maize price leadership

The extended VAR procedure Toda and Yamamoto (1995) causality test employed to analyse the lead-lag price relationships among regional wholesale maize markets. The findings from Toda and Yamamoto causality test indicate that Addis Ababa maize market price movement influences the surplus wholesale maize markets of Hosaena, Nekemete, and Nazareth[4]. Likewise, Addis Ababa maize market price dictates maize price determination of all deficit regional maize markets considered in this study. Therefore, the null hypothesis of no causality from Addis Ababa maize price to the above-mentioned surplus and deficit maize markets has been rejected. In the majority of cases, the direction of causation is

[4] Unit root and Toda and Yamamoto causality test results are not reported here, but full results will be provided upon request.

unidirectional from Addis Ababa price to the rest regional maize markets. The converse, however, does not hold except for the deficit Dese maize market. Apart from this one case, Addis Ababa maize price is exogenous to the rest regional maize markets. Thus, Addis Ababa's wholesale maize market is behaving like a dominant maize market in Ethiopia. The geographical advantage enables Addis Ababa wholesale maize market to have large number of feeder markets, which further contributes to unidirectional price influence.

4.4 Long-run relationships

Since the price series are non-stationary and integrated of the same order, cointegration analysis is therefore appropriate to investigate the long-run relation among wholesale maize market prices. Given the large number of maize markets, cointegration tests are conducted in a pairwise fashion. Following the results of T-Y causality test, Addis Ababa maize market is treated as exogenous maize market. Thus, in the subsequent cointegration analysis, regional wholesale maize markets are paired with Addis Ababa maize market.

The results for the cointegrated maize market pairs are presented in Table 6. Cointegration results from Johansen tests shows that no cointegration were found between Addis Ababa with Debre-Markos, Hosaena, Shashemene, and Nazareth maize market pairs. Given the proximity of Nazareth and Addis Ababa, absence of cointegration between the two wholesale maize markets was not expected. The two markets are located within the radius of 86.5 km and are connected with good all-weather roads. One possible cause for no cointegration between Nazareth and Addis Ababa maize market could be the presence of structural breaks, which may lead to misleading inference on cointegration results. It is widely accepted that the presence of structural breaks distorts the validity of conventional unit root and cointegration tests (Phillips, 1986; Perron, 1989). The Bai and Perron (1998) multiple structural break test is employed to detect the presence of structural breaks on wholesale maize market prices. The use of Bai and Perron test is motivated by the possible presence of structural breaks created by government intervention in attempt to curb the crisis of food price surge in 2008 and 2011.

Table 6: Cointegration tests among wholesale maize market prices

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*	$r = 0$	23.81***	r=0	20.09**	2
	$r \leq 1$	3.72	r=1	3.72	
Addis - DB*	$r = 0$	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	

*BD and DB stand for Bahir Dar and Debre-Birhan markets
***, ** significance level at 1 and 5%

The results for structural breaks on wholesale maize market prices are presented in Table 7. The sequential Bai and Perron test results identified 15 breakpoints. The 2008 M07, M10, M11, and M12 structural breaks are likely associated with the Ethiopian government macroeconomic intervention. In March 2008, the government restricted foreign exchange access to private traders. The 2009, 2010, and 2012 breaks are perhaps the delayed effects of global commodity price crisis of 2008 and 2011.

Table 7: Bai-Perron test results and break dates for regional markets with Addis Ababa wholesale maize market

Markets	**Gondar**	**BD**	**Mek'ele**	**Hosaena**	**DM**	**Dese**	**Nazareth**	**Nekemete**	**Shashemene**	**Ziway**	**Critical value**
Tests						**Scaled F-statistics**					
sup-F(1|0)	41.49**	35.15**	14.09**	27.51**	27.03**	19.97**	45.19**	13.77**	52.37**	21.58**	11.47
sup-F(2|1)	41.32**	37.48**	22.41**	32.29**	10.32	9.23	7.80	10.47	9.89	5.39	12.95
sup-F(3|2)	32.11**	21.19**	17.11**	8.84							14.03
sup-F(4|3)	17.91**	3.38	14.39								14.85
sup-F(5|4)	0.00										15.29
Break dates	2007M01, 2008M11, 2012M01, 2014M07	2008M11, 2011M11, 2014M06	2008M11, 2012M01, 2014M05	2008M10, 2011M05	2012M12	2008M07	2008M12	2009M11	2013M01	2012M05	

Notes: BD and DM stand for Bahir Dar and Debre-Markos markets
** denotes rejection of the null hypothesis at 5% significance level

In general, the results from the Bai and Perron test reveal that the presence of structural break is evident in maize market prices and they might have an impact on cointegration test. Therefore, it is important to retest cointegration among wholesale maize markets by considering the effects of structural breaks. Following Rafailidis and Katrakilidis (2014), we estimated the Dynamic Ordinary Least Square approach (DOLS) to investigate cointegration test by incorporating the identified structural breaks in the form of dummy variables. Analysing cointegration by taking into account breaks gives a different story for maize markets considered as non-cointegrated in the Johansen's approach (see tables 8 and 9). Regional maize markets (Shashemene, Nazareth, Debre-Markos, and Hosaena) that are found to have no-cointegration with Addis Ababa maize market have become cointegrated when structural breaks are taken into account.

Table 8: DOLS estimation for Hosaena and Debre-Markos maize markets

Hosaena and Addis Ababa market pairs		
Variables	**Coefficients**	**t-Statistic**
Panel A. Long run equilibrium results from DOLS		
ADDIS_ABABA	1.15***	44.53
Constant	-21.61**	-2.21
HOS08	-87.86*	-1.75
HOS11	62.92	1.34
Adj. R^2	0.95	
Panel B: Cointegration test for the market pairs		
U_t = -2.25**		
Debre-Markos and Addis Ababa market pairs		
Panel A. Long run equilibrium results from DOLS		
ADDIS_ABABA	1.15***	24.28
Constant	-35.64**	-1.99
DM12	46.97	0.55
Adj. R^2	0.94	
Panel B: Cointegration test for the market pairs		
U_t = -2.79***		

Notes: Leads and lags specifications are based on AIC criterion
U_t is the innovation series obtained by dynamic ordinary least squares cointegration equation.
***, **, * denotes rejection of the null hypothesis at 1%, 5%, and 10% significance level

Table 9: DOLS estimation for Nazareth and Shashemene maize markets

Nazareth and Addis Ababa market pairs		
Variables	**Coefficients**	**t-Statistic**
Panel A. Long run equilibrium results from DOLS		
ADDIS_ABABA	1.06***	33.78
Constant	-18.43	-1.53
NAZ08	40.48	0.68
Adj. R^2	0.95	
Panel B: Cointegration test for the market pairs		
U_t = -2.47**		
Shashemene and Addis Ababa market pairs		
Panel A. Long run equilibrium results from DOLS		
ADDIS_ABABA	1.11***	23.84
Constant	-29.21	-1.65
SHASH13	159.75*	1.89
Adj. R^2	0.92	
Panel B: Cointegration test for the market pairs		
U_t = -2.74**		

Notes: Leads and lags specifications are based on AIC criterion
U_t is the innovation series obtained by dynamic ordinary least squares cointegration equation.
***, **, * denotes rejection of the null hypothesis at 1%, 5%, and 10% significance level

5. CONCLUSIONS

This study aimed at examining the price formation and dynamics in the Ethiopian maize market. Furthermore, we empirically tested the central maize market hypothesis. Results from the central market hypothesis test indicate that Addis Ababa wholesale maize market serves as an important hub for maize market price formation, and more importantly as a hotspot for source of maize price shocks, which influence the short and long-run price fluctuations of regional maize markets. Spatial maize market cointegration tests were conducted by taking into account structural breaks. Cointegration tests reveal that all regional maize markets paired with the central market are cointegrated. The cointegration 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).

Appendix Table 1: List of endogenous and exogenous variables

Variables	Description	Units
Macro-economic variables		
CPIF	Consumer Price Index (CPI): Food	Index (2000=100)
RPCGDP	Real GDP per Capita	USD/person
POP	Total population of Ethiopia	millions
Policy variables		
SHIFT 2004	A shift variable for the period of soaring food prices in the domestic grain markets	1 for period since 2004 and 0 otherwise
SHIFT 2008	A shift variable for government price stabilization interventions	1 for period since 2008 and 0 otherwise
SHIFT 2011	A shift variable for export ban on maize	1 for period since 2011 and 0 otherwise
Deflated price variables		
RPMAIZE	Real maize price	ETB/t
RWHEAT	Real wheat price	ETB/t
RPWHEATP	Real wheat producer price	ETB/t
RPMAIZEP	Real maize producer price	ETB/t
Weather variables		
RAINL	Average rainfall for area for the months of March and April	mm
RAINP	Average rainfall for production for the months of May, June, July, August and September	mm
Trend and input variables		
IRRIG	Irrigated maize area	Ratio
SEED	Maize planted with improved seed	Ratio
LNTREND	Log linear trend to capture the effect of maize technological improvement	Logarithm
TREND	Trend variable for change in consumption habit	Time trend
Supply and demand variables		
Yield	Yield of maize	tons/ha
AREA	Area of maize planted	1000 ha
BEGSTOCK	Beginning stock	1000 tons
MPROD	Domestic maize production	1000 tons
FED	Feed and residual	1000 tons
DMCON	Human consumption	1000 tons
SED	Seed	1000 tons
TMUSE	Total domestic use	1000 tons
ESTOCK	Ending Stocks	1000 tons
PMC	Per capita maize consumption	kg/person

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