Price Cointegration Analyses of Food Crop Markets: The case of Wheat and *Teff* Commodities in Northern Ethiopia

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Summary

This paper examines the cointegration of grain market prices in Northern Ethiopia. Results are based on bi-monthly retail price data on wheat and teff collected from six markets in the Tigray region of Northern Ethiopia. The data has 55 observations for each of the two crops in each of the six markets ranging over a period of May 2006 to October 2008. Johansen's cointegration test reveals that most markets are cointegrated in wheat and *teff* retail prices. There is an indication that retail prices at Abi-Adi, a town located relatively farther away from the main asphalt road, is less integrated to other markets. This implies that infrastructural development is crucial for spatial market integration through market information transmission and physical transfer of goods from one market to another.

Key words: price cointegration, food crop market, error correction model.

JEL: C31, C32, Q13

1. Introduction

Markets play important roles in facilitating the exchange of goods and services and can be welfare enhancing for actors engaged in the exchanges. Markets also provide signals about the true cost of resources and guide allocation to their best use. In addition to signals about the value of resources, integrated markets could help in equalizing the value of a resource across space after accounting for transfer costs between markets (Baulch, 1997).

[1] *Teff* is a cereal crop endemic to Ethiopia and widely grown next to maize and wheat.

In most cases, agricultural markets in developing countries are less integrated due to lack of well developed infrastructure and market institutions that facilitate the easy flow of goods and information between markets (Minten, 1999). Majority of the rural agricultural markets in Ethiopia share this feature. Under such circumstances, rural markets may not be able to make quick adjustments to price shocks occurring in neighboring market.

So far, studies on grain market integration in Ethiopia are mainly focusing on how the regional market prices are cointegrated to the central grain market in Addis Ababa (Negassa, 1998; Dercon, 1995; Kinde, 2005). Such studies are relevant since the Addis Ababa grain market is the core in grain price determination. However, fewer attempts are made in trying to examine how local markets are cointegrated and adjusting to price shocks in their neighboring markets or to their immediate regional market. With this understanding, this paper tries to analyze the extent of food crop market integration in northern Ethiopia using retail prices.

The remaining part of this paper is organized as follows. Section 2 presents the empirical framework used in the analysis. Section 3 describes the study area and data used. Empirical results are presented in section 4. Section 5 presents conclusions and implications.

2. Price cointegration model

If two markets are said to be spatially integrated, prices in a given market adjust to the price shocks in the other market. This price adjustment between markets may take place through the flow of goods from surplus to deficit areas. Such transfer usually occurs when the observed shocks are able to cover the transfer cost of goods from one market to the other. Even if prices in two markets are cointegrated, sometimes one may not know a prior the direction of price adjustments taking

place between these markets. In such a case, it is advisable to use vector error correction model (VECM) since it estimates the adjustment parameters to the long-run equilibrium (Meyer, 2004).

2.1. Vector Error Correction Model specification

If commodity prices at all markets follow an integrated process of order 1, i.e., I(1), vector error correction model that accounts for trends and a constant term is specified as:

$$\Delta p_t = \Pi p_{t-1} + \sum_{i=1}^{L-1} \Gamma_i \Delta p_{t-i} + \nu + \delta t + \varepsilon_t \quad (1)$$

Where Δp_i a vector of *mx1* first difference is prices from *m* markets and Π is a coefficient matrix and point of interest to test for cointegration and adjustments between markets. If Π has a reduced rank of $r<m$, then there exist *nxr* matrices of α and β each with rank *r*, such that $\Pi = \alpha\beta'$, where α is a vector of adjustment coefficients, and β is a vector of the cointegration equation parameters. $\Gamma_1,...,\Gamma_{L-1}$ are parameters of the lagged short-term reactions to the previous price changes (Δp_{t-k}) in all markets. δ is a parameter of trend and ν is a constant term. Here one should note that since the VECM equation specified above is based on first differences, the constant implies a linear time trend in the differences, and the time trend (δt) implies a quadratic time trend in the levels of the data (StataCorp, 2007:364). ε_t is a vector of *mx1* disturbance term assumed to be identically and independently distributed. L refers to the number of lags determined from the vector autoregressive (VAR) analysis.

2.2. Estimation procedure using VECM approach

A three stage procedure could be followed to test for a price cointegration between or among markets and estimate the adjustment parameters using VECM. In the first step, using the augmented Dickey-Fuller (ADF) unit root test, the series of commodity prices in different markets are tested for stationarity. Once the stationarity is confirmed, the number of maximum lags to be included in the cointegration test or the cointegrating VECM estimation is identified. Though there are a number of criteria that could be used in selecting the lag orders, Akaike Information Criterion (AIC) is the most common one.

Using the selected lag orders, the Johansen's (1988, 1991) method is applied to test the existence of cointegration between or among a series of market prices. The Johansen's cointegration method rejects the null hypothesis of no cointegration ($r=0$) when the log-likelihood of the unconstrained model that includes the cointegrating equations is significantly different from the log-likelihood of the constrained model that does not include the cointegrating equations. If the commodity prices in all markets are integrated process of order 1, *I(1)*, but not cointegrated, then the coefficient matrix Π becomes a zero matrix and thus has rank zero. Johansen's cointegration test gives the number of ranks (i.e., the available cointegration equation vectors). If there is a vector of cointegration equation(s) identified from this test, the existence of cointegration between/among the markets is confirmed and estimates of the cointegration equations are also obtained.

After the cointegration test, the VECM is estimated to obtain the adjustment parameters to the long-run equilibrium.[2] However, inferences on the adjustment coefficient estimates ($\hat{\alpha}$) are

[2] Recent studies criticize conducting market integration analyses without accounting for transaction costs (Barrett, 2001; Barrett and Li, 2002; Meyer, 2004, among other). Meyer (2004) argues that Threshold Vector Error Correction Models (TVECM) can account for the effects of transaction costs in price transmission analysis. However, due to the limited number of price observations we have, we could not use the TVECM, though more appropriate. Therefore, we

dependent crucially on the stationarity of the cointegrating equations. Thus, the model specification should be checked for stationarity. Finally, an impulse-response graph can be plotted for selected market prices to examine visually whether a price shock in one market has either a permanent or transitory effect on the prices in other markets.

3. Study area and data description

Grain market price data used in this study was collected by the Tigray Agricultural Marketing Promotion Agency (TAMPA) on bi-monthly basis from selected ten market towns in Tigray Regional State of Northern Ethiopia. Based on the completeness of price data over the study period, retail prices of wheat and *teff* crops in six market towns (Abi-Adi, Alamata, Axum, Hawzen, Maichew and Mekelle) are considered in this analysis. Geographical locations of these selected market towns and road networks connecting them with each other are presented in figure 1.

are cautious in interpreting the adjustment parameter estimates in this study. We focus more on the direction than the magnitude of adjustments between markets.

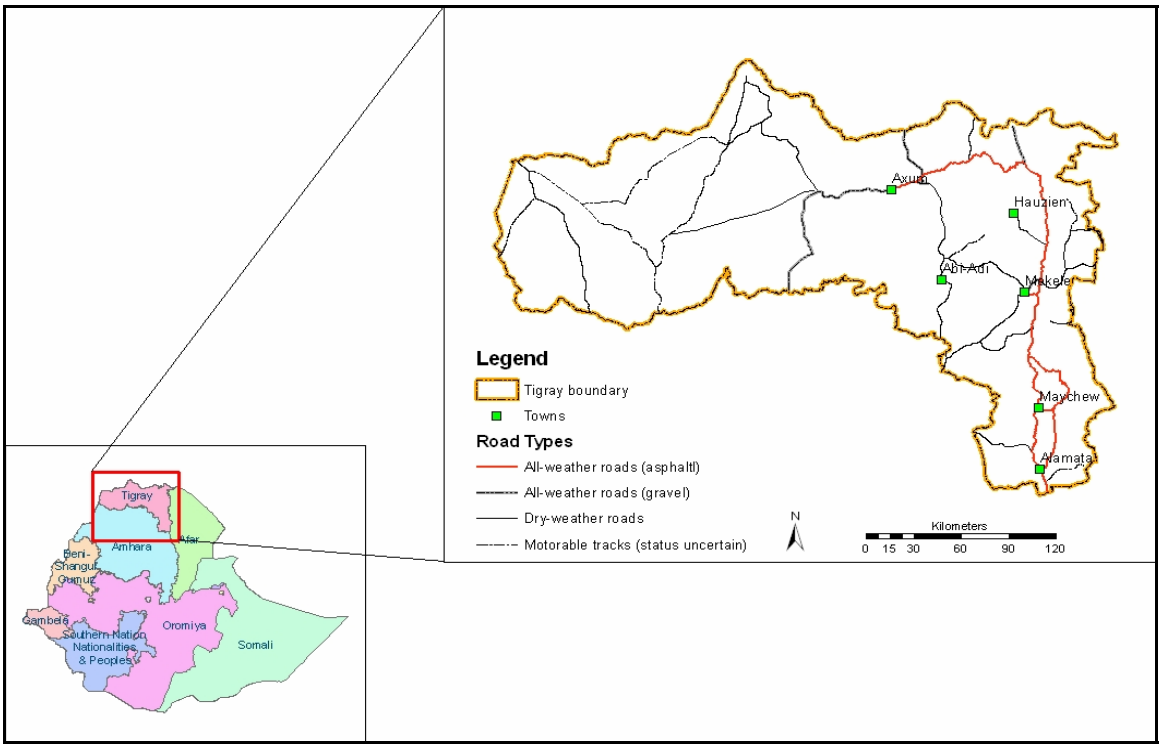

Figure 1. Geographical locations of market towns and the road network

There are a total of 55 retail prices for each commodity in each market recorded on bi-monthly basis starting from May 01, 2006 to October 01, 2008.[3] The retail price data for wheat and *teff* shows that there is an overall upward trend in price movements over time. In all markets and for both crops, retail prices follow relatively stable movement from May 01, 2006 to October 16, 2007 (which is assigned to be *period 1* in the remaining part of the paper). But from November 2007 onwards *(period 2*), there is a sharp increase from time to time except for the last few observations in September and October 2008. Figures 2 and 3 show the bimonthly retail prices of wheat and *teff* in the selected market towns, respectively.

[3] Four retail price observations in 2006 (mid-May, mid-October, and early and mid-November) are missing in all markets.

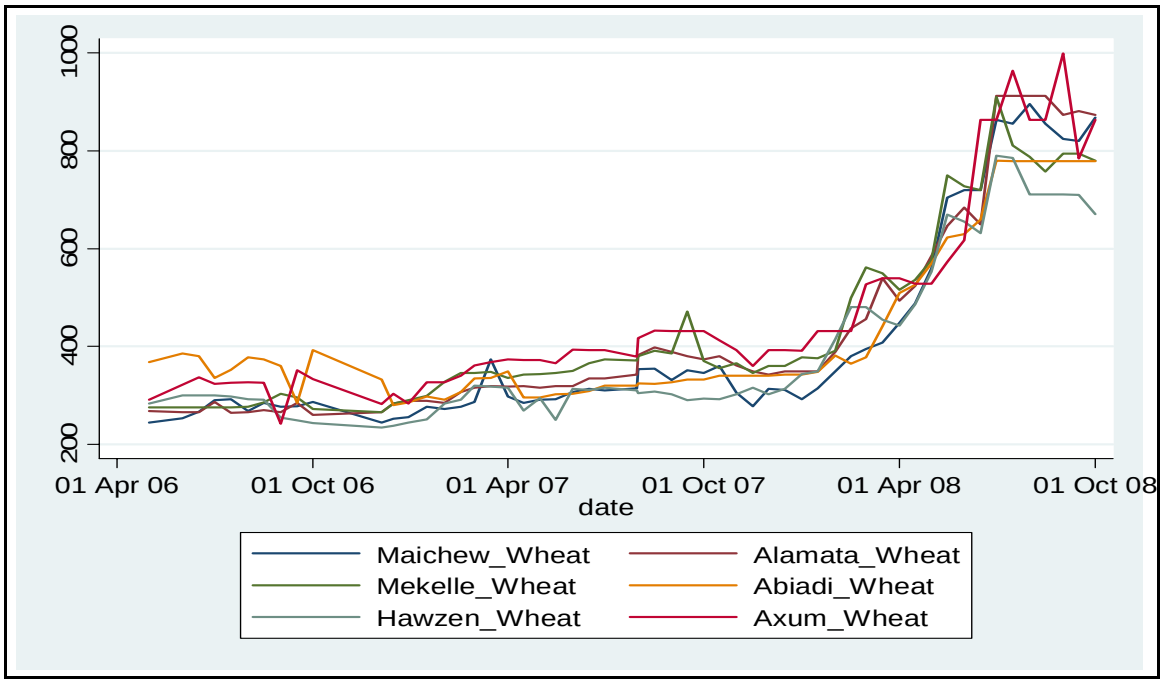

Figure 2. Wheat retail prices at the selected market towns (Birr/quintal) [4]

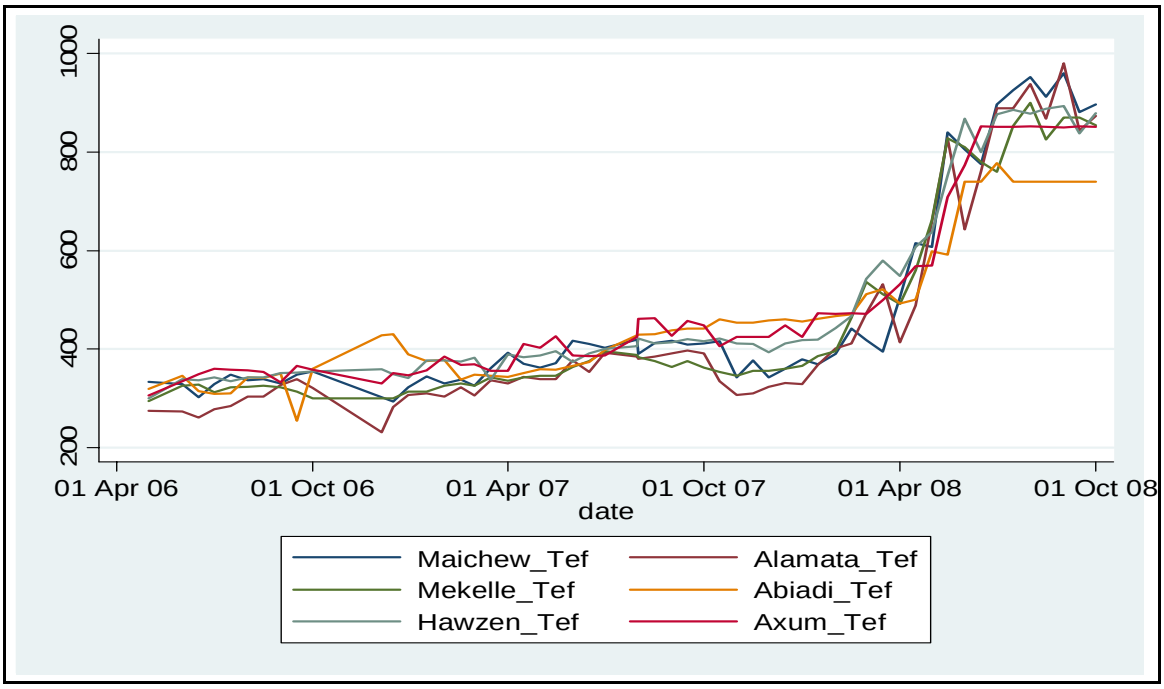

Figure 3. *Teff* retail prices at the selected market towns (Birr/quintal)

[4] Birr is the Ethiopian Currency (1USD=9.7Birr at the time of this study).

It is difficult to judge on the kind of relationship between commodity retail prices in different markets based on figures 2 and 3. There is no clear indication that a given market may always have higher or lower prices. The way these markets respond to shocks in a given market is also difficult to analyze visually.

4. Empirical analyses and results

4.1. Stationarity test

Since wheat and *teff* retail prices in all market towns experienced a visible difference in trend for the two periods, it might be possible that the price data in these two periods may follow a different stationarity process. Baum (2001) argues that the conventional augmented Dickey-Fuller (ADF) test for stationarity may lead to a wrong conclusion specially if there is structural break in the data. For this reason, the ADF unit root test is applied to the two successive periods and the whole data set. At 5% critical level, results in table 1 show that the ADF unit root test could not reject the null hypothesis that the price series are unit root for the two commodities, at all market towns, and across the two specified periods.

Table 1. Augmented Dickey-Fuller (ADF) unit root test at 5% significance level

Commodity type	Market town	Period 1* (n=32)	Period 2 (n=23)	Whole period (n=55)
		Test statistic**	Test statistic	Test statistic
Wheat	Maichew	-2.210	-2.959	-1.984
	Alamata	-2.833	-2.417	-2.036
	Mekelle	-2.607	-2.370	-1.636
	Abi-Adi	-1.747	-2.268	-1.618
	Hawzen	-2.668	-2.036	-1.899
	Axum	-1.570	-2.567	-1.946
Teff	Maichew	-2.062	-2.463	-2.101
	Alamata	-1.924	-2.415	-2.201
	Mekelle	-2.783	-2.103	-2.148
	Abi-Adi	-1809	-1.988	-1.656
	Hawzen	-1.467	-2.393	-1.992
	Axum	-1.514	-1.866	-1.602

Note: * The whole period (May 01, 2006 - October 01, 2008) is decomposed into two periods: Period 1 (May 01, 2006 to October 16, 2007, which has 32 observations) and period 2 (November 01, 2007 to October 01, 2008, with 23 observations).

** The 5% critical levels for period 1, 2, and 3 are -3.596, -3.600 and -3.498, respectively.

4.2. Weak exogeneity (Granger causality) test

The Engle-Granger causality test could give some indications for the existence of cause and effect relationships between retail prices in different markets. Accordingly, except for wheat prices in Hawzen, there are weaker Granger-causalities from the aggregate market town retail prices. Relatively stronger causality is seen on wheat retail prices in Axum from all market towns except

Hawzen. Two weeks earlier retail prices in Mekelle market Granger-cause wheat retail prices in Maichew, Alamata and Axum markets. Similar effects from Mekelle market is seen on *teff* retail prices in Abi-Adi, Hawzen and Axum markets. However, only Hawzen market Granger-causes both wheat and *teff* retail prices in Mekelle market. Details are presented in table 2 below where only the significant Chi-square values are reported.

Table 2. Granger causality Wald (Chi-square) test results on the bimonthly retail prices

Commodity	Market town	Causing market town						
		Maichew	Alamata	Mekelle	Abi-Adi	Hawzen	Axum	ALL
Wheat	Maichew			13.72***	12.46***			40.38***
	Alamata			7.50**			18.89***	65.16***
	Mekelle					7.63**		18.70**
	Abi-Adi	5.63*					16.20***	49.00***
	Hawzen						6.01**	
	Axum	16.95***	8.93**	5.15*	4.77*			98.62***
Teff	Maichew		6.80**			9.14**		40.43***
	Alamata	5.76*					5.30*	63.10***
	Mekelle					6.21**		23.89***
	Abi-Adi			4.74*			6.97**	43.92***
	Hawzen	11.97***		28.70***				75.95***
	Axum			7.48**	8.09**			66.37***

Note: χ^2 test with 2 degrees of freedom (df) for the specific market towns and 10 df for all markets.
***, **, and * significant at 1%, 5% and 10% levels, respectively.

4.3. Long term price cointegration relationship

First, we tested whether the bivariate cointegration between pair of markets is different for the two distinct price movements in period 1 and 2. There is no consistent outcome to make a general conclusion whether the cointegration of retail prices is different for the two periods (a period with

more stable prices and a period with consistently increasing prices). Thus, we shifted to the whole set of retail price observations to test for the long term price cointegration.

The existence of long term cointegration relationship in retail prices for wheat and *teff* in different markets is tested using the Johansen's method. The number of lags to be considered in each pair of markets tested for cointegration is selected using Akaike Information Criterion (AIC).

Johansen's bivariate cointegration test shows that, in the long-run, most of the market towns are cointegrated to each other both in wheat and *teff* retail prices (Table 3 and 4). Table 3 shows that, at 5% significance level, except the Abi-Adi-Maichew and Alamata-Axum pairs, there is a significant long term cointegration relationship in all market pairs. The lack of cointegration between Alamata and Axum could be due to the relatively longer distance between the two markets. But, that of Abi-Adi and Maichew could be due to the fact that Abi-Adi is located farther away from the main asphalt road passing through most of the market towns (figure 1).

Table 3. Bivariate Johansen's co-integration test for wheat retail prices (time trend is included)

	Maichew	Alamata	Mekelle	Abi-Adi	Hawzen
Alamata	**25.8352**[a] 1.2846*[b]				
Mekelle	**26.6331** 1.1056*	**40.6037** 3.0623*			
Abi-Adi	18.1298* 0.5301	**20.2573** 0.9013*	**21.2659** 1.2293*		
Hawzen	**18.1891** 2.5045*	**26.7730** 4.6700 *	**23.6526** 3.1795*	**22.0537** 2.3595*	
Axum	**36.5318** 0.6634*	15.9374 0.8221*	**40.6219** 1.3148*	**18.3217** 4.4116*	**25.3182** 9.4010 *

Note: [a] Trace statistic for a maximum rank (r) of zero.
[b] Trace statistic for a maximum rank (r) of one.

* Accept H_0 at 5% significance level. The 5% critical values for the hypothesis H_0: r = 0, H_1: r $\geq$ 1 and H_0: r = 1, H_1: r $\geq$ 2 are 18.17 and 3.74, respectively. Thus, trace statistic greater than 18.17 are indicating that there is at least one cointegration equation.

At 5% significance level, three pairs of markets are not significantly cointegrated in *teff* retail prices. These pairs are: Abi-Adi-Maichew, Abi-Adi-Mekelle and Hawzen-Maichew. *Teff* retail prices at Abi-Adi market happened to be not significantly cointegrated in two of the three failed pairs (Table 4). As indicated above, this might be due to its geographical location and relatively poor road condition connecting this market town to Mekelle, Axum and other markets. Though not as far as Abi-Adi, Hawzen is also located away from the main asphalt road (figure 1).

Table 4. Bivariate Johansen's co-integration test for teff retail prices (time trend is included)

	Maichew	Alamata	Mekelle	Abi-Adi	Hawzen
Alamata	**31.6107** [a] 6.5908*[b]				
Mekelle	**21.3514** 0.5338*	**19.8092** 0.8298*			
Abi-Adi	13.3736* 4.5095	**24.1284** 1.6503*	17.0796* 0.8975		
Hawzen	12.2236* 0.0000	**24.7565** 3.7848 *	**26.4470** 9.4504 *	**20.1222** 1.0785*	
Axum	**36.5318** 0.6634*	**29.7828** 2.2603 *	**24.1016** 1.6522*	**19.6653** 2.5752*	**35.8860** 0.7637 *

Note: [a] Trace statistic for a maximum rank (r) of zero.
[b] Trace statistic for a maximum rank (r) of one.
* Accept H_0 at 5% significance level. The 5% critical values for the hypothesis H_0: r = 0, H_1: r $\geq$ 1 and H_0: r = 1, H_1: r $\geq$ 2 are 18.17 and 3.74, respectively. Thus, trace statistic greater than 18.17 are indicating that there is a cointegration of at least with one rank.

The Johansen's cointegration test results in table 3 and 4 are showing the long term cointegration relationship. However, they fail to tell the direction of causalities and the adjustments made between markets when there are price shocks. To capture the direction of causalities and adjustments, obtaining the VECM estimation results with the estimates of the adjustment parameters is important.

Accordingly, table 5 and 6 presents estimates of the adjustment parameter ($\hat{\alpha}$) in the VECM specification. These estimates for the paired markets show how one market adjusts to the long-run equilibrium when the retail price changes in its own market or other market are too high. For instance, positive and significant values show how retail prices in the adjusting markets are quickly adjusting to the higher price shocks in the other market. On the other hand, negative values show how the higher retail prices in adjusting markets quickly fall back towards the retail prices of the other market (StataCorp, 2007: 369). Estimated adjustment coefficients closer to |1| indicate that the retail price adjustment in a given market is so quick.

Accordingly, results in table 5 show that wheat retail prices in Axum market adjust quickly to the higher retail prices observed in all other markets. However, higher retail prices in Axum market is not significantly adjusting back to the lower retail prices in any of these markets. This shows that the wheat retail price adjustment in Axum market is asymmetric.

Table 5. VECM estimates of the adjustment parameters for wheat retail prices

		Adjust to					
		Maichew	Alamata	Mekelle	Abi-Adi	Hawzen	Axum
Adjusting markets	Maichew		-0.0818 *(0.3319)*[a]	-0.1617 *(0.1019)*	0.3401** *(0.1219)*	-0.2607*** *(0.0912)*	-0.0769 *(0.0883)*
	Alamata	1.0491*** *(0.2993)*		-0.8323*** *(0.1587)*	-0.4954*** *(0.1267)*	-0.6403*** *(0.1347)*	-0.4265 *(0.5585)*
	Mekelle	0.3168* *(0.1225)*	-0.1529 (0.2279)		-0.4138** *(0.1406)*	-0.7061*** *(0.1774)*	0.0141 *(0.6493)*
	Abi-Adi	0.1602 *(0.1096)*	0.6114 (0.117)	0.2159** (0.0996)		-0.2965*** *(0.1114)*	0.0795 *(0.0964)*
	Hawzen	0.0679 *(0.0969)*	-0.2986 (0.1395)	-0.1276 (0.1603)	0.2351* (0.1355)		0.0175 *(0.2489)*
	Axum	0.6911*** *(0.1028)*	1.5681** 0.5026	2.3316*** (0.4185)	0.5782*** (0.1677)	0.7698*** (0.2152)	

Note: [a] Figures in parenthesis are standard errors.
***, **, and * are significant at 1%, 5%, and 10% level.

Table 6. VECM model estimates of the adjustment parameters for *teff* retail prices

		Adjusting to					
		Maichew	Alamata	Mekelle	Abi-Adi	Hawzen	Axum
Adjusting markets	Maichew		-0.3932*** *(0.1480)*[a]	-0.4678*** *(0.1520)*	-0.1360* *(0.0789)*	-0.4348*** *(0.1518)*	-0.4028*** *(0.1457)*
	Alamata	0.6154*** *(0.1848)*		-1.3163*** *(0.2850)*	-0.3103*** *(0.0943)*	-0.6948*** *(0.1504)*	-0.0370 *(0.3182)*
	Mekelle	0.1406 *(0.1226)*	-0.4765** *(0.1780)*		-0.0115 *(0.0711)*	-1.1558 *0.1648*	-0.1699 *(0.1524)*
	Abi-Adi	0.2527 *(0.0479)*	0.1939*** *(0.0524)*	0.2907*** *(0.5641)*		-0.5754*** *(0.1313)*	-0.5969*** *(0.1478)*
	Hawzen	0.2442** *(0.1068)*	0.2462*** *(0.0886)*	0.6980*** *(0.1164)*	-0.0537 *(0.1437)*		0.0889 *(0.1967)*
	Axum	0.2772*** *(0.0881)*	0.5656*** *(0.1434)*	0.5549*** *(0.0967)*	0.1719 *(0.1449)*	0.6521*** *(0.1421)*	

Note: [a] Figures in parenthesis are standard errors.
***, ** and * are significant at 1%, 5% and 10% level.

Similar to adjustments in wheat retail prices, except to Abi-Adi market, *teff* retail prices in Axum are adjusting to higher prices in other markets (Table 6). However, higher retail price shocks in Abi-Adi and Maichew quickly adjusts back to Axum's level. Teff retail prices in all markets are adjusting to Mekelle and Alamata markets whereas Mekelle adjusts only to Alamata market.

Finally, using the whole set of selected markets and the number of lags obtained from the VAR analysis by Akaike Information Criterion (AIC), the Johansen's test for co-integration is implemented. The test shows that there are 3 and 2 cointegrating equations identified for wheat and *teff* prices, respectively (table 7 and 8). Apart from the bivariate cointegration analyses discussed above, this shows that out of the six markets, there are at least three and two markets that are cointegrated at a time in wheat and teff retail prices, respectively.

Table 7. Johansen's cointegration test results for wheat retail prices in all markets

Trend: trend [a]				Number of observations 49	
Sample: 7 - 55				Lags 4	
Maximum rank	Parameters	Log-Likelihood	Eigenvalue	Trace Statistic	Critical value (5%)
0	120	-1333.85	.	188.1337	104.94
1	131	-1295.26	0.79304	110.9464	77.74
2	140	-1273.66	0.58595	67.7401	54.64
3	147	-1256.50	0.50357	33.4243*	34.55
4	152	-1249.08	0.26126	18.5868	18.17
5	155	-1243.25	0.21185	6.9213	3.74
6	156	-1239.79	0.13173		

Note: [a] A linear trend is used in the cointegrating equations while a quadratic trend is used in the undifferenced data.
[*] Accepting the null hypothesis H_0: r =3 at 5% significance level.

Table 8. Johansen's cointegration test for *teff* retail prices in all markets

Trend: trend [a]				Number of observations 51	
Sample: 5 - 55				Lags 4	
Maximum rank	Parameters	Log-Likelihood	Eigenvalue	Trace Statistic	Critical Value (5%)
0	120	-1351.69	.	157.9420	104.94
1	131	-1319.44	0.71765	93.4470	77.74
2	140	-1296.22	0.59770	47.0080****	54.64
3	147	-1283.16	0.40088	20.8814	34.55
4	152	-1276.46	0.23115	7.4759	18.17
5	155	-1272.85	0.13185	0.2649	3.74
6	156	-1272.72	0.00518		

Note: [a] A linear trend is used in the cointegrating equations while a quadratic trend is used in the undifferenced data.
[*] Accepting the null hypothesis H_0: r =2 at 5% significance level

Mekelle is a central and economically important town in the region. Taking this into account, whether unexpected retail price shocks happening in Mekelle market may have either a permanent or transitory effect in the remaining markets is analyzed using an impulse-response graph (see figure A1 and A2 at Annex). Accordingly, unexpected wheat retail price shock that is local to Mekelle market has a permanent effect in Alamata and Maichew markets. The effect is transitory in the remaining three markets. However, unexpected shock on *teff* retail prices in Mekelle market has a permanent effect in all markets.

5. Conclusions and implications

Due to the poor infrastructural and institutional facilities, agricultural commodity markets in developing countries are commonly less integrated. This study tried to test agricultural commodity markets integration in Northern Ethiopia. VECM analyses results show that most of the markets are cointegrated to each other both in wheat and *teff* retail prices. Retail prices in Abi-Adi market, which is located relatively farther away from the main asphalt road passing through other markets, are found to be less cointegrated to other markets in the long-run.

Comparing the two crops, cointegration is more observed for wheat than *teff* retail prices. This might be due to the fact that wheat is relatively largely produced in the region while, in most cases, *teff* is transported to the region from the neighboring regional states. Compared to *teff*, unexpected retail price shocks in wheat retail prices at Mekelle market have relatively a transitory effect on retail prices in other markets. *Teff* retail price shocks in Mekelle have more of a permanent effect in other markets. In general, results of this study imply that infrastructural developments like roads and market information system are crucial for market information transmission and physical transfer of goods from one market to another.

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Annexes

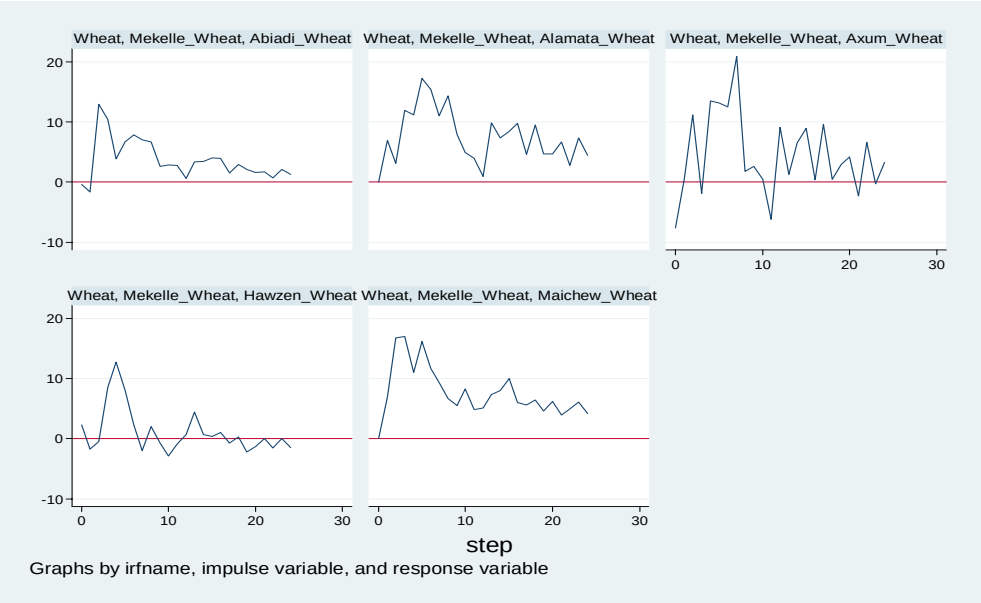

Figure A1. Impulse-response graph for unexpected wheat retail price shocks in Mekelle market.

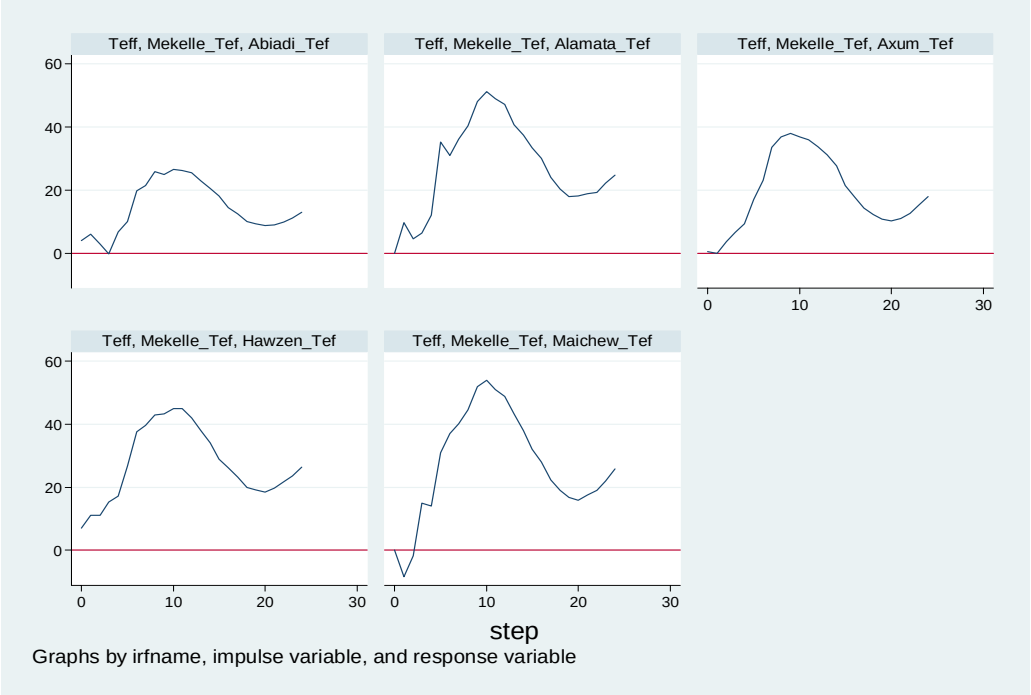

Figure A2. Impulse-response graph for unexpected *teff* retail price shocks in Mekelle market.