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Full Length Research Paper

Price co-integration analyses of food crop markets: The case of wheat and *teff* commodities in Northern Ethiopia

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This paper examines the role of market price information dissemination on the co-integration of grain market prices in Northern Ethiopia. Results are based on bi-monthly retail price data on wheat and *teff* commodities 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 from May, 2006 to October, 2008. Johansen's co-integration test reveals that most markets are co-integrated in wheat and *teff* retail prices. However, 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, in addition to market price information dissemination, other infrastructural developments like road networks are crucial for spatial market integration through the physical transfer of goods from one market to another.

Key words: Price co-integration, food crop market, error correction model.

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). In most cases, agricultural markets in developing countries are not well 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. Recently the Tigray Agricultural Marketing Promotion Agency (TAMPA) introduced a market price information dissemination process using local public media in the Tigray region, Northern Ethiopia. TAMPA collected agricultural market prices from 10 markets on 15 agricultural commodities including wheat and *teff*. The price information was analyzed at TAMPA head quarter in Mekelle and transmitted to the public via local radio regularly. It is believed that such initiatives contribute towards creating the *'Rule-of-one-Prices'* through a better co-ordinated and integrated markets. So far, studies on grain market integration in Ethiopia are mainly focusing on how the regional market prices are co-integrated to the central grain market prices in Addis Ababa (Negassa, 1998; Dercon, 1995; Getnet et al., 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 co-integrated and adjusting to price shocks in their neighboring markets or to their immediate regional market. Such analysis is helpful in identifying the level of

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integration of local markets with each other and identifying factors that re-quire attention in order to improve integration at regional level. This paper is, therefore, aimed at analyzing the extent of food crop market integration in the Northern Ethiopia region of Tigray using retail prices.

The remaining part of this paper is organized as follows. First, the empirical framework used in the analysis is presented and followed by description of the study area and data used. Then, empirical results are presented and discussed. Finally, it concludes and gives implications.

PRICE CO-INTEGRATION 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 the two markets are co-integrated, sometimes one may not know prior the direction of price adjustments taking place between these markets. Granger causality test could show how the lagged prices in one market could affect prices in the other market (Granger, 1969; Engel and Granger, 1987). However, this test does not give how long the effect of a given price shock in one market might take till the price in the other affected market adjusts to equilibrium. 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). These well known methodologies are briefly discussed subsequently.

Granger causality test

As indicated earlier, Granger causality test could give a clue on the existence of potential causality and direction of causality between prices in different markets. Granger causality between prices of two markets A and B is specified as:

$$p_t^A = \sum_{i=1}^{k} \alpha_i p_{t-i}^A + \sum_{i=1}^{k} \beta_i p_{t-i}^B + u_{Ai} \quad (1a)$$

and

$$p_t^B = \sum_{i=1}^{k} \mu_i p_{t-i}^B + \sum_{i=1}^{k} \tau_i p_{t-i}^A + u_{Bi} \quad (1b)$$

where p_t^A and p_t^B are prices at period t in markets A and B, respectively. α, β, μ and τ are parameters to be estimated. k is the maximum number of lagged prices included in the model.

The null hypotheses to be tested in Granger causality is $H_0 : \beta_1 = \beta_2 = ... = \beta_k = 0$ for a situation where price in market B is expected to Granger cause price in market A, and $H_0 : \tau_1 = \tau_2 = ... = \tau_k = 0$ when price in market A is expected to Granger cause price in market B.

Vector error correction model specification

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

$$\Delta p_t = \Pi p_{t-1} + \sum_{i=1}^{L-1} \Gamma_i \Delta p_{t-i} + \nu + \delta t + \varepsilon_t \quad (2)$$

where Δp_t a vector of *m* × 1 first difference is prices from *m* markets and Π is a coefficient matrix and point of interest to test for co-integration and adjustments between markets. If Π has a reduced rank of $r < m$, then there exist $n \times r$ 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 co-integration 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 earlier 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 $m \times 1$ disturbance term assumed to be identically and independently distributed. L refers to the number of lags determined from the vector autoregressive (VAR) analysis.

Estimation procedure using VECM approach

A three stage procedure could be followed to test for a price co-integration between or among markets and estimate the adjustment parameters using VECM. In the first step, using the augmented Dickey-Fuller (ADF) unit root test (Dickey and Fuller, 1979), the series of commodity prices in different markets are tested for stationarity. ADF test for a stationarity with a linear time trend *(t)* is specified as:

$$\Delta p_t = \alpha + \beta p_{t-1} + \delta t + \varsigma_1 \Delta p_{t-1} + \varsigma_2 \Delta p_{t-2} + ... + \varsigma_k \Delta p_{t-k} + u_t \quad (3)$$

where α, β, δ and ς are parameters to be estimated using OLS method. The null hypothesis to be tested for unit root is $H_0 : \beta = 0$. For a data with *T* observations, the maximum number of lags ($k_{\max}$) to be included in the ADF specification could be set using Schwert (1989) method, which is specified as:

$$k_{\max} = \text{int}[12\{T+1)/100\}^{0.25}] \tag{4}$$

Once the stationarity is confirmed, the number of maximum lags to be included in the co-integration test or the co-integrating 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 method of Johansen (1988, 1991) was applied to test the existence of co-integration between or among a series of market prices. The Johansen's co-integration method rejects the null hypothesis of no co-integration (*r = 0*) when the log-likelihood of the unconstrained model that includes the co-integrating equations is significantly different from the log-likelihood of the constrained model that does not include the co-integrating equations. If the commodity prices in all markets are integrated process of order 1 I(1), but not co-integrated, then the coefficient matrix Π becomes a zero matrix and thus, has rank zero. Johansen's co-integration test gives the number of ranks (that is, the available co-integration equation vectors). If there is a vector of co-integration equations identified from this test, the existence of co-integration between/among the markets is confirmed and estimates of the co-integration equations are also obtained. After the co-integration test, the VECM is estimated to obtain the adjustment parameters to the long-run equilibrium.[1] However, inferences on the adjustment coefficient estimates ($\hat{\alpha}$) are dependent crucially on the stationarity of the co-integrating equations. Thus, the model specification should be checked for stationarity. Finally, an impulse-response graph can be plotted for selected market prices to examine virtually whether a price shock in one market has either a permanent or transitory effect on the prices in other markets.

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) were considered in this analysis. Geographical locations of these selected market towns and road networks connecting them with each other are presented in Figure 1.

There are a total of 55 retail prices for each commodity in each 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.

EMPIRICAL ANALYSES AND RESULTS

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) argued that the conventional augmented Dickey-Fuller (ADF) test for stationarity may lead to a wrong conclusion especially, 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 shows 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.

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 was seen on wheat retail prices in Axum from all market towns except Hawzen. Two weeks earlier, retail prices in Mekelle market Granger caused wheat retail prices in Maichew, Alamata and Axum markets. Similar effects from Mekelle market was seen on *teff* retail prices in Abi-Adi, Hawzen and Axum markets. However, only Hawzen market Granger caused both wheat and *teff* retail prices in Mekelle market. Details are presented in Table 2 where only the significant Chi-square values are reported.

Long term price co-integration relationship

First, we tested whether the bivariate co-integration between pair of markets is different for the two distinct price movements in periods 1 and 2. There is consistent

[1]Recent studies criticize conducting market integration analyses without accounting for transaction costs (Barrett, 2001; Barrett and Li, 2002; Meyer, 2004, among other). Meyer (2004) argued 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 are cautious in interpreting the adjustment parameter estimates in this study. We focus more on the direction than the magnitude of adjustments between markets.

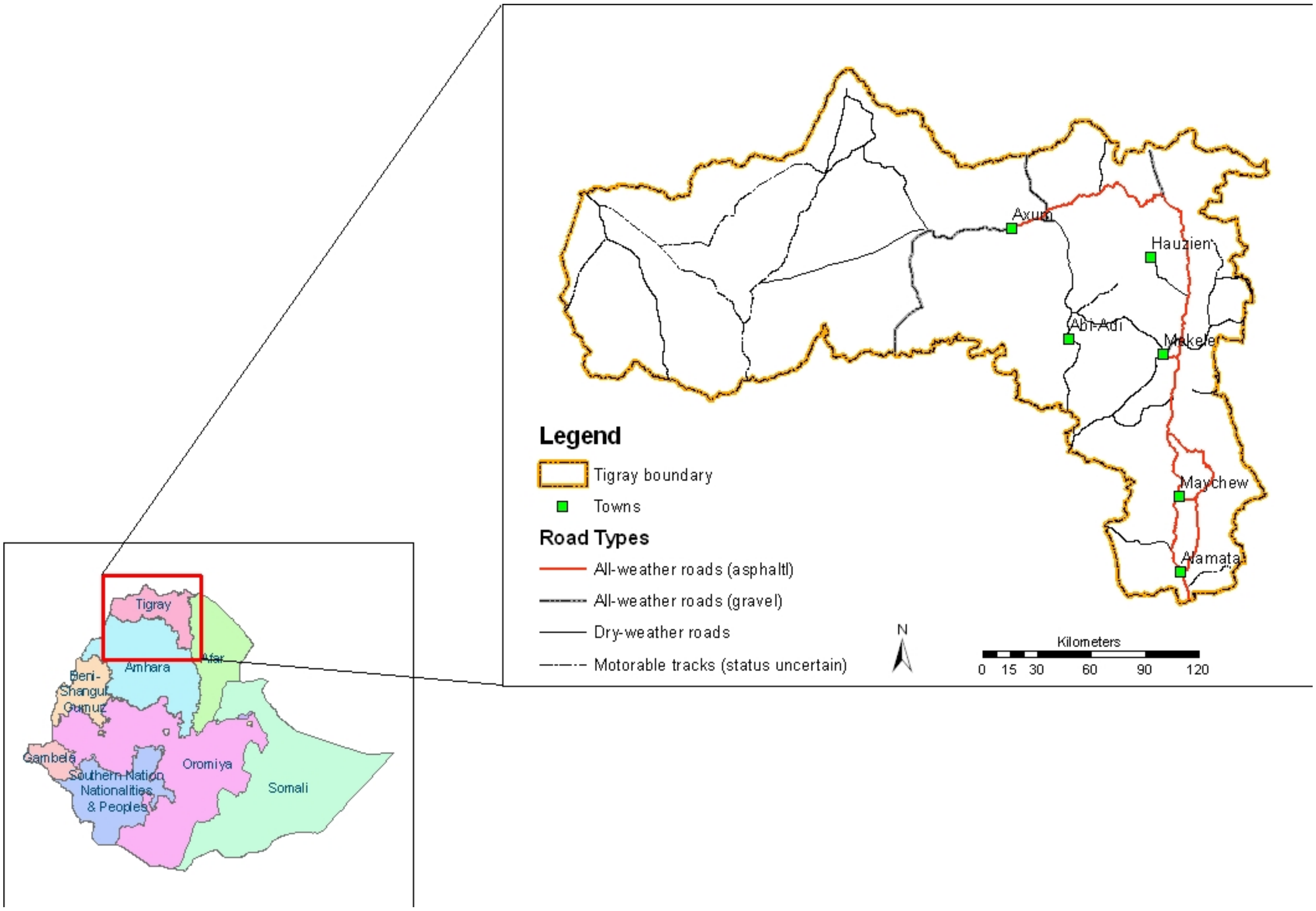

Figure 1. Geographical locations of market towns and the road network.

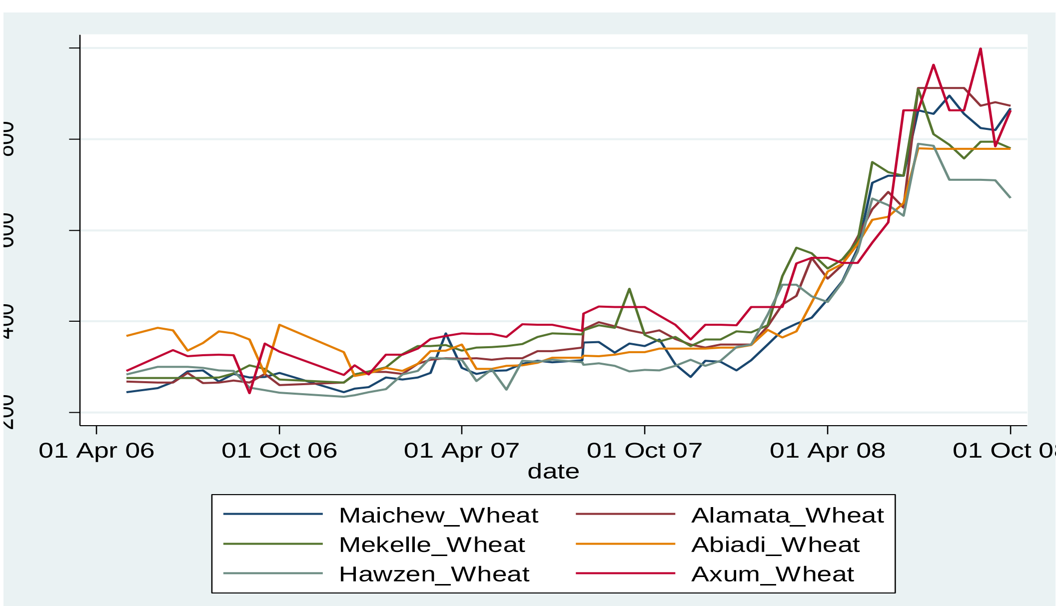

Figure 2. Wheat retail prices at the selected market towns (Birr/quintal).

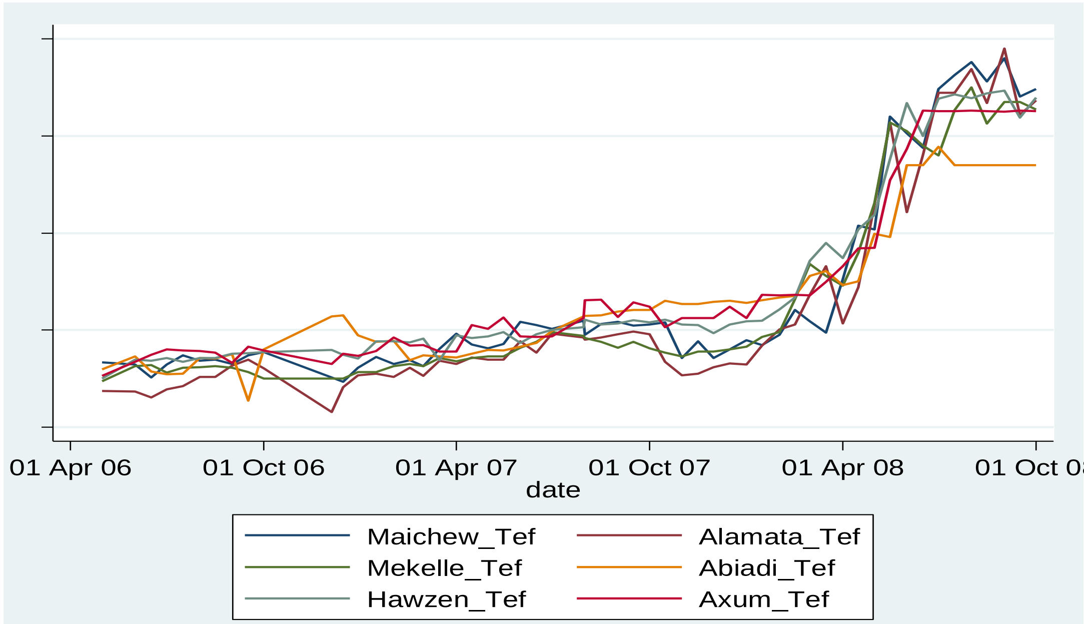

Figure 3. *Teff* retail prices at the selected market towns (Birr/quintal).

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

* The whole period (May 01, 2006 - October 01, 2008) is decomposed into two periods: Period 1 (May, 1st 2006 to October, 16th 2007, which has 32 observations) and period 2 (November, 1st 2007 to October, 1st 2008, with 23 observations). ** The 5% critical levels for periods 1, 2, and 3 are; -3.596, -3.600 and -3.498, respectively.

outcome to make a general conclusion whether the co-integration 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 co-integration.

The existence of long term co-integration 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 co-integration is selected using Akaike Information Criterion (AIC). Johansen's bivariate co-integration test shows that, in the long-run, most of the market towns were co-integrated to each other both in wheat and *teff* retail prices (Tables 3 and 4). Table 3 shows that, at 5% significance level, except for the Abi-Adi-Maichew and Alamata-Axum pairs, there is a significant long term co-integration relationship in all market pairs. The lack of co-

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***

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.

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

Variable	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*

[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 co-integration equation.

integration 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).

At 5% significance level, three pairs of markets were not significantly co-integrated 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 co-integrated in two of the three failed pairs (Table 4). As indicated earlier, 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).

The Johansen's co-integration test results in Tables 3 and 4 show the long term co-integration relationship. However, they fail to tell the direction of causalities and

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

Variable	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*

[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 co-integration of at least with one rank.

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, Tables 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 changes in the retail price of its own market or of other markets 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 the study of Babiker and Abdalla (2009) indicate that the retail price adjustment in a given market is so quick (Rapsomanikis et al., 2003; Babiker and Abdalla, 2009).

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 adjusted back to the lower retail prices in any of these markets. This shows that the wheat retail price adjustment in Axum market is asymmetric. Similar to adjustments in wheat retail prices, except to Abi-Adi market, *teff* retail prices in Axum adjusted 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 adjusted 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 co-integrating equations identified for wheat and *teff* prices, respectively (Tables 7 and 8). Apart from the bivariate co-integration analyses discussed earlier, this shows that out of the six markets, there are at least three and two markets that are co-integrated at a time in wheat and teff retail prices, respectively.

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 (Supplementary Figure A1 and A2). 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.

Conclusions

Due to poor infrastructural and institutional facilities, agricultural commodity markets in developing countries are commonly not well integrated. Based on the market price information transmission efforts TAMPA is making, this study is aimed at testing agricultural commodity markets integration in Northern Ethiopia. Analyses results using Vector Error Correction Model (VECM) showed that most of the markets considered under this study are

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

Variable		Adjusting 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(0.1170)	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) ***	

[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.

Variable		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) ***	

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

Table 7. Johansen's co-integration test results for wheat retail prices in all markets.

Trend: trend [a]		Log-likelihood	Number of observations 49		
Sample: 7 - 55			Lags 4		
Maximum rank	Parameters		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		

[a] A linear trend is used in the co-integrating 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 co-integration test for *teff* retail prices in all markets.

Trend: trend [a]		Log- likelihood	Number of observations 51		
Sample: 5 - 55			Lags 4		
Maximum rank	Parameters		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		

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

integrated to each other both in wheat and *teff* retail prices. However, 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 co-integrated to other markets in the long-run. Comparing the two crops, co-integration 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 implies that market price information transmission could help in integrating local markets through adjustments to markets with higher prices, suggesting the role of market information transmission systems. Results also showed that road and transport infrastructure development that facilitate the physical transfer of goods could make a difference in the integration of grain markets. Our results implies that public policies in Ethiopia could play critical roles in facilitating market integration and thereby, market efficiency through the development of agricultural market information systems and road infrastructure.

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APPENDIX

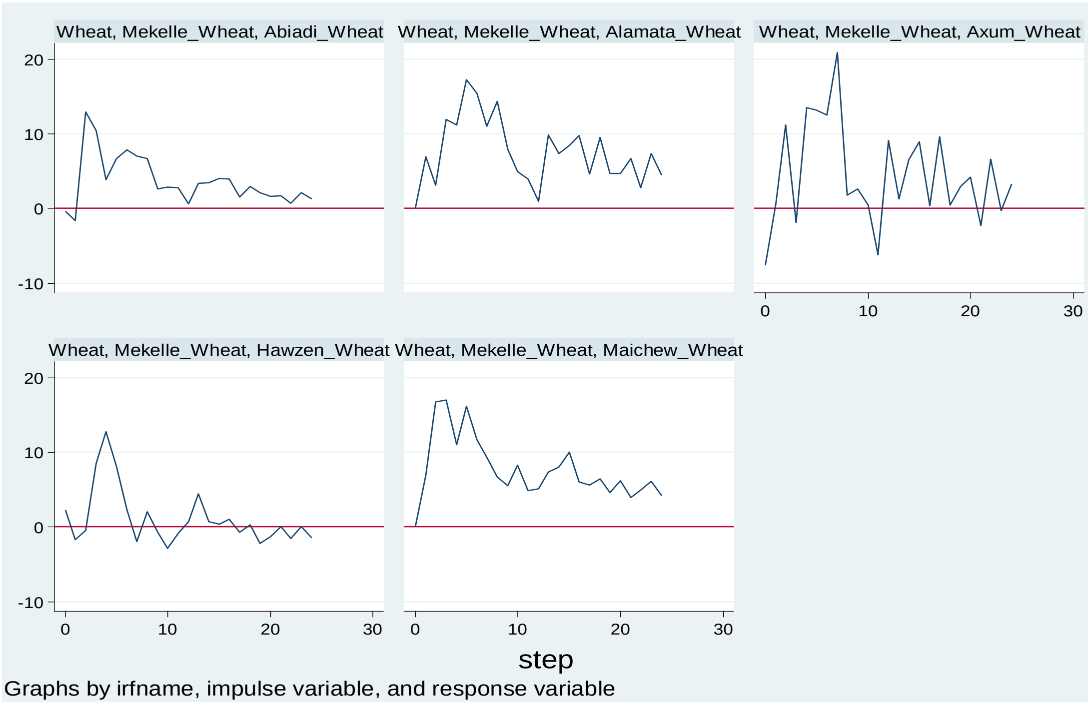

Figure A1. Impulse-response graph for unexpected wheat retail price shocks in Mekelle market.

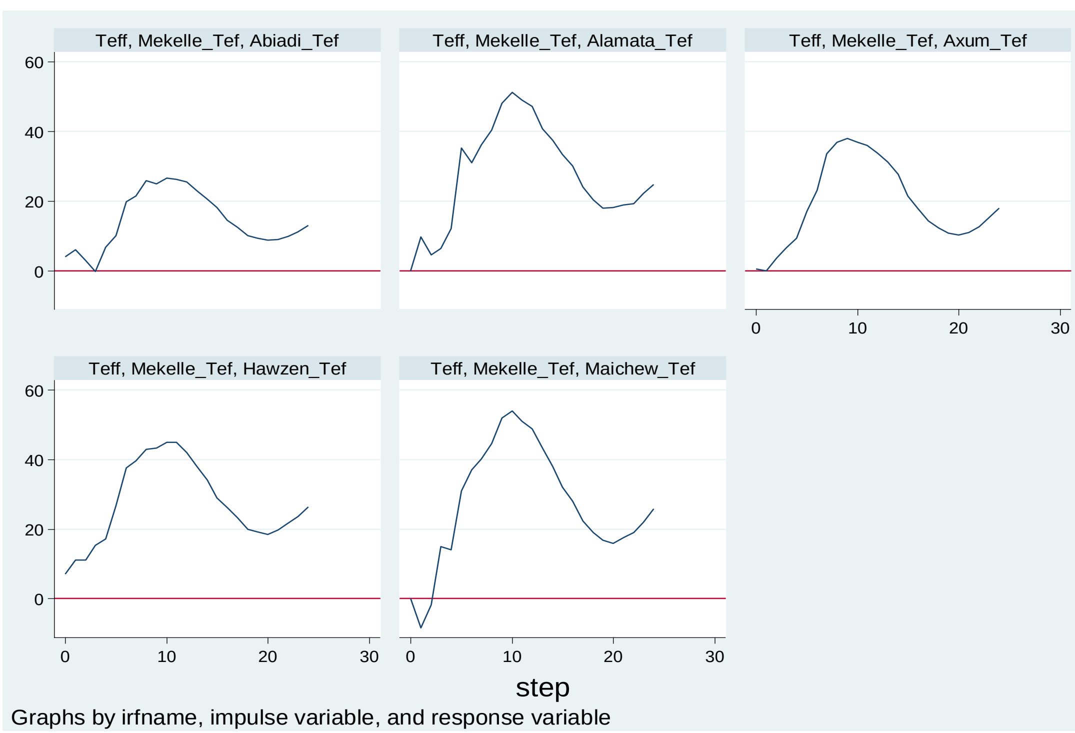

Figure A2. Impulse-response graph for unexpected *teff* retail price shocks in Mekelle market.