SPATIAL INTEGRATION OF BULLS AND OXEN MARKETS IN ETHIOPIA

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Abstract

This study investigates the extent and efficiency of integration in bulls and oxen markets in Ethiopia. Market integration and efficiency analyses are the crux of policy debates on liberalization, pricing policy, and restructuring marketing institutions and infrastructure. Improved integration of markets in cattle surplus and final demand areas benefit farmers, as market price and other information flow fast between these markets. This leads to improved commercialization of production, which is currently only at its infancy, consequently leading to improvements in quality and quantity of cattle supplied. Threshold autoregressive model was applied on CSA monthly price data of bulls and oxen collected at 115 points in time during the July 2001-January 2011 period, covering 50 markets. Results of analysis lead to 5 observations, with exceptions in each of the cases and animal types. First, close intraregional markets are more often integrated than those that are apart. Second, interregional markets are integrated when close to each other, mainly along micro trade routes serving major trade routes and marketing sheds, both suggesting proximity of markets helps better integration. Third, a large number of market pairs are integrated in prices of both cattle types than in only one. Moreover, perform in terms efficiency was relatively similar in both cattle markets and whether the markets are integrated in only one or both cattle price. Fourth, more interregional markets are integrated in only bulls' prices than in oxen. Larger frequency of integration in bulls markets than in oxen among non-local markets appears to support descriptive analysis that found three-quarters of cattle are traded amongst farmers that largely buy older cattle for draught power from local markets. Unlike oxen, bulls are destined for end-consumption and they are moved across regional boundaries, which are integrated in bulls' prices more frequently. Finally, nationwide as well as regional relative threshold values declined significantly among all groups and cattle types. This may have resulted from improvements in physical infrastructures and improvement in marketing information.

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1. Introduction

The issue of market integration and market efficiency is at the center of policy debates aimed at deciding whether or not to liberalize markets, on pricing policy, at restructuring marketing institutions, and infrastructure to help better integrate markets and achieve marketing efficiency.[2] This study investigates the extent and efficiency of integration in bulls and oxen markets in Ethiopia. Such analysis is particularly important in the Ethiopian context where government's effort to control skyrocketing retail food prices proved futile. The failed price control which lasted for about 5 months starting from February 2011 suggests finding alternative solutions that comprise the entire food value chain and its participants.

Data from Central Statistical Agency of Ethiopia (CSA) is used to first characterize the live cattle production subsector. We survey previous works to characterize cattle marketing. Moreover, descriptive analysis of CSA price data is used to characterize price movements in cattle markets. The descriptive analysis is meant to provide insights regarding size, purposes, and rate of commercialization of cattle production.

Investigating the extent of integration helps understand how markets in rural surplus producing areas respond to price changes in downstream markets. For this purpose we apply threshold autoregressive analysis on cattle price data of 40 markets in Ethiopia covering the 2001-2010 period. Given the large number of markets representing all administrative regions, the study will better help understand whether and how price signals are transmitted, which in turn helps understand how gains from trade are shared. The analysis will also enable us to simultaneously investigate if the markets are operating efficiently under the circumstances. Such a study is particularly important when price differentials between two markets exceed transaction costs, implying inefficient integration, whether or not there is trade between the markets.

In this work we use threshold autoregressive (TAR) model, which together with parity bounds model (PBM), represent a workhorse of recent market integration analyses. The justification for using this approach is that, although TAR models do not explicitly include transaction costs as do PBM, they recognize that there exist thresholds created by transaction costs, which price differentials must exceed before equilibrating price

[2] For a formal definition of the concepts of market efficiency and integration one can glance at the beginning of section 3.

adjustments that lead to market integration occur (Goodwin and Piggiot 2001). Moreover, the specific TAR model we will be using allows for time varying thresholds it will account for transaction costs that change over time, thereby providing a better measure of market integration relative to earlier models that fix thresholds, which is a restrictive assumption given that transaction costs are more likely to change through time.

There are five sections in this paper. The following section will characterize cattle production, marketing, extent of commercialization, and trends in cattle prices. The third section will provide details of the theoretical model used in this study. Results will be presented and discussed in the fourth section. The last section summarizes the key findings.

2. Characteristics of Cattle Production and Marketing and Data Description

During the 2003/4-2009/10 period, for which Central Statistical Authority of Ethiopia (CSA) published annual reports on ownership and activities involving livestock, the number of livestock averaged just over 44 million and grew at average annual rate of 5 percent to get to 51 million in 2009/10 from 38 million in 2003/4.[3] The number of male and female livestock averaged 45 and 55 percent of the total and annual growth among the respective sexes averaged 5.3 and 4.7 percent. Cattle of ages 0-12 months, 1-3 years, 3-10 years, 10 and older averaged 17.5, 16, 63, and 3 percent of the herd, and grew at average annual rates of 5.4, 3.3, 3.9, 3.5, 6.3, and 1 percent, respectively. Out of the 63 percent 3-10 year olds 25, 19, 15, and 0.7 percent were used for draught power, breeding, dairy, and fattened for beef; and grew at an average annual rate of 5.5, 13, -0.4, and 11.5 percent, respectively.

The data indicate that indigenous cattle represented 99.3 percent of the cattle population while the rest were either hybrid or exotic. However, the number of hybrid and exotic species increased considerably, growing at an average annual rate of 9 and 21 percents, respectively. Descriptive analysis presented in subsection 2.1 indicates that cattle production in Ethiopia is almost entirely traditional as producers use little modern inputs and have low market participation. We also provide some survey of literature

[3] Only 2 of the 5 and 3 of the 9 zones in pastoralist areas of Afar and Somali regions, respectively, are included in annual CSA reports. Data for the remaining zones are not included in the reports for they constitute mainly nomadic households. The reader should take into account the fact that the descriptive analysis in this and the following sections do not include data from these zones and interpret the results accordingly.

highlighting the nature of cattle markets in subsection 2.2. Subsection 2.3 will describe the monthly price data used in the analysis spanning the July 2001-January 2011 period.

Characteristics of cattle production and commercialization.

Domestic Animal Genetic Resources Information System that identified and mapped five local breeds (Jabbar et. al. 2007). The Borena breed dominates the Borena area of Oromia region. The Ogaden breed dominates the Somali lowland region, the Arsi and Horro breeds are predominantly located in central and western Oromia regions, and the Fogera breed dominates central Amhara. While the first two are located in mainly pastoralist areas the last three are in predominantly settled areas that mix cattle production with crop production. In addition to Arsi and Borena, the Danakil, Harar, Raya Azebo, and Zebu breeds are identified by ILRI (ILRI 2011).

Out of the 13.9 million farm households in Ethiopia in 2008/9, about 80 percent owned 1 or more cattle.[4] The proportion of households that own cattle was even lower among the important pastoralist areas of Afar and Somali regions and the Borena zone of Oromia with 24, 33, and 21 percent of the households reporting to have owned no cattle in 2008/9, respectively. Nationally 53 percent of the households owned 4 heads or less, while this number was 20 percent in Afar, 33 percent in Somali, and 39 percent in Borena. During the same year, nationally, 21 and 5 percent owned 5-9 and 10-19 heads, while these numbers were 20 and 21 percent in Afar, 20 and 11 percent in Somali, and 23 and 14 percent in Borena.

Using number of cattle per total area, Jabbar et. al. (2007) find the largest number of cattle along the north–south transect of central highlands of Tigray, Amhara, and Oromia regions, and that connecting Nazareth and Dire Dawa. Low cattle density occurred in pastoral areas of Afar, Somali, and Borena. Livestock population densities per 1000 human population implied that areas with higher human population densities also had higher livestock densities, especially in parts of Tigray and northeastern and southern parts of the country. Some lowland pastoral areas also had moderate to high densities, as pastoral herd sizes were larger relative to those practicing small-scale mixed farming. Econometric results show that livestock density initially increases and then declines with increasing human population density (Jabbar et. al. 2007).

[4] Unless stated otherwise, data presented in the following paragraphs refer to the 2008/9 agricultural season using CSA (2009).

The focus provided for Afar and Somali regions and the Borena zone in Oromia is because a large proportion of the households depend entirely on their herd for their livelihood. On average, the number of cattle per household stood at 10.2, 4.2, and 5.7 in Afar, Somali, and Borena, respectively, relative to the national average of 3.6. Moreover, cattle density per household member was 1.7, 0.7, and 1.4 in the respective areas relative to the national average of 0.7. The number of cattle per hectare of total agricultural land was 3.2 nationwide while it was 15.7, 4.5, and 12.4; in Afar, Somali, and Borena, respectively. The number of cattle per hectare of grazing land was 84.5 in Borena, which has complete data on grazing area, while it was 35.6 nationwide.

The purposes cattle serve differ in pastoralist and mixed crop-animal farming areas. Among the 3-10 years old cattle only 6, 18, and 13 percent are meant for draught power in Afar, Somali, and Borena, respectively, smaller than the 25 percent national average. Nationally, 15 percent of these cattle produce milk; this number averaged 32 percent in pastoralist areas. Moreover, these pastoralist areas supply 95 percent of livestock destined for export market (Legesse et. al. 2008).

An overuse of locally available resources results in competition and conflicts over grazing fields and water resources. This problem is commonplace in pastoralist lowlands of Ethiopia. In a July 2011 trip to northeastern Amhara region we witnessed a similar conflict between settled mixed crop-animal farming households of highland and lowland areas. Informal interview revealed that the highlanders, who intended migrating through the lowland areas in search of grazing land as all land is covered with meher season crops, were chased away with their emaciated cattle by the lowlanders. One possible way to convert this potential into an asset is help farmers gear their production towards marketing the cattle. Such efforts should be conscious of the cultural values and purposes associated with the cattle, and be tailor made to suit settled and pastoralist cattle production systems.

About 12.3 million or 25 percent of the cattle were sold, slaughtered, died, or offered to others in 2008/9. Only 3 percent were slaughtered and about 4 percent offered to others. The most important source of destocking, cattle deaths, accounted for 52 percent, followed by 41 percent sold. About three quarters of the trade occurred amongst farmers, accounting for 3.6 of the 5 million traded. That is, only 28 percent of the cattle traded were destined for final consumption (net-commercial off-take).[5] Relative to the 0.8 percent 3-10 year old cattle fattened for beef this net-commercial off-take rate, which represented 3 percent of the entire cattle population is large. This likely implies the cattle sold for final consumption were of low quality, as the excess of net-commercial off-take rate over those fattened for beef more likely represents disposal of older draught cattle. The little integration with market is pronounced among pastoral households. While 30, 20, and 38 percent of stock reductions in Afar, Somali, and Borena were due to sales, 67, 78, and 58 percent of destocking was due to death. However, trade among households in the respective areas was relatively lower as net-commercial off-take rates averaged 89, 87, and 76 percent of the cattle traded.

Cattle production is largely traditional with little integration to inputs markets. Out of the 11.2 million households that owned cattle in 2008/9 about 61 percent fed their herd green fodder and grazing, 27 percent used crop residue, and 7 percent used hay. Only 0.8 percent used improved feed and other byproducts. Most of the feed came from own resources, as only 6 percent of households purchased animal feed. A large proportion of cattle are produced through traditional methods. In 2008/9 only 0.5 and 0.4 percent of cattle holders practiced dairy development and beef/meat/mutton extension packages, respectively. Although 19 percent of the cattle were afflicted with diseases and 13 percent died, the proportion vaccinated was 26 percent. Given the significant proportion vaccinated, such a huge loss through death implies lower rate of detection of diseases or onset of epidemic, or such services are unavailable in some pockets, particularly among pastoralists that move periodically.

The brief characterization provided above indicate both little integration of cattle production with markets among both sedentary and pastoralist households. Commercializing cattle production provides an untapped opportunity to increase the quality and quantity supplied from both systems, Particularly, integrating mixed crop-cattle producing households with the market provides an alternative means of livelihood and reduce the pressure on land.

Factors affecting market participation, marketing sheds and routes, and marketing problems

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[5] Net-commercial off-take rate is the proportion of sales net of those traded between farmers for reproductive and draught purposes out of average beginning and ending cattle inventory.

Among factors that resulted in low net-commercial off take rates low cattle productivity is notable. Negassa and Jabbar (2008) note that low birth and high mortality rates lead to low herd and flock productivities among sedentary and pastoralists alike, resulting in low net-commercial off-take rate. That is, the main factor influencing households' choice of market participation is herd size. Moreover, land holding size significantly affected market participation (Negassa and Jabbar 2008).

The solutions proposed to increase heard size include the following. Designing appropriate feeding and health management practices and disseminating the messages through improved extension services. Extension messages should aim at improving productivity through increasing fertility, reduced mortality, and increased feed conversion ratio, and advises to improve the quality of cattle produced and market participation. Increased investment in animal health services should be made as a prerequisite for increased cattle productivity. Policies encouraging commercial livestock production help increase supply. Recommended also are the development of appropriate institutions, policies and marketing infrastructure, and support services (Negassa and Jabbar 2008).

Using CSA survey data on cattle marketing, Jabbar et. al. (2007) identified primary, secondary, and tertiary markets located in four marketing sheds. These constitute Tigray, Amhara, Oromia, and SNNP sheds that principally serve market routes in each catchment. They identified 24, 25, 43, and 24 micro-routes serving the respective marketing sheds. The authors indicate that the eastern and south eastern lowlands supply cattle for the highland domestic markets and to those serving exports to the Gulf regions and Kenya. Markets in Nazareth, Shashemene, Mekelle and other large cities, which are supplied by a wide range of areas, serve as terminal or semi-terminal markets. Addis Ababa is the largest domestic terminal market supplied by nearly the entire. Somalia constitutes the most important destination for cross-boundary cattle trade originating from Ethiopia. The second largest source is the south eastern Ethiopia-south western Somalia-north eastern Kenya triangle. The latest cross-border trade occurred through the north western border with Sudan. Similarly, two routes serving the cross-border trade between Djibouti and Ethiopia originating from southern Afar and Dire Dawa regions were identified (Jabbar et. al. 2007).

Eight groups of marketing agents are identified by Legese et. al. (2008). Pastoralist and mixed-farming producers supply almost all the cattle while collectors buy the cattle to supply big, medium, and small-scale traders. The remaining participants are feedlot operators that fatten cattle for different markets, big traders that purchase a large number of animals from different sources, exporters that use official channel to deliver live animal and meat to different countries, livestock trading cooperatives, and brokers. The low performance of the marketing system was attributed to problems in marketing infrastructure and non-infrastructure factors. Improving the available road network, better services in market centers and provision of waiting areas will improve the marketing. Among non-infrastructure factors clan conflict resulting from competition for resources is notable. Strengthening traditional solution mechanism is suggested as a major solution (Legese et. al. 2008).

3. Description of price data used in the analysis

Monthly retail price data extending the July 2001-January 2011 period was collected from 116 bulls and 117 oxen markets representing all regions of the country. Among four cattle categories we chose oxen and bulls because they have better commercial off-take rates relative to cows and heifer.

Bulls prices

During the July 2001-December 2010 period, average annual change in real bulls prices ranged from a decline of 2 percent in Tigray to the fastest growth rates of 14 and 7.6 percent in Harari and Afar regions, respectively (Table 1). [6] Growth rate in Addis Ababa markets, 1.7 percent, was the second slowest and was mainly dominated by the 40 percent growth rate during 2003-2004. Anecdotal findings, based mostly on informal interviews of cattle traders, indicate that regional average cattle prices are partly affected by cross-border trade. But we cannot confirm this from the price data used in this study. Moreover, most of the regions with fastest growing prices have little cross-border trade. A follow up work that complements this study using a different data set investigates the issue of cattle price formation using an Hedonic price formation analysis (Bachewe and Headey, forthcoming). However, even in that work accounting for the effect of cross-border trade had proved problematic. Nationwide, annual growth rate averaged 3.4 percent; growth was fast during 2005-2006 and it declined fast during 2007-2008. Averaged across the years, real prices of 2-4 year old bulls were lowest in

[6] We concede that regional average prices would have been more informative had weights measuring the relative importance of each market in regional price averages, such as volume of sells, were used. Since this variable not available we use simple averages.

SNNP and Afar regions at 622 and 719 birr (2006 prices) while they were highest in Tigray and Addis Ababa with average real price of 1,015 and 1,153. Nationwide, bulls prices averaged 803 birr across in the period, the lowest and highest being 633 and 989 birr that occurred in 2003 and 2007.

Real prices grew faster at 4.2 percent between 2005 and 2010 relative to the 2.3 percent between 2001 and 2005. The fast increase in the latter period is pronounced in nominal prices which grew at 23 percent relative to the 11 percent between 2001 and 2005. During the 2001-2010 periods, nominal prices grew at an average annual rate of 18 percent starting from the national average of 408 birr in 2001 to 1,676 in 2010.

Table 1: Regional average annual real prices of bulls (2 - 4 years old)[a]

Region	Year									
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Tigray	1062	1182	998	1063	1013	977	1051	1001	950	853
Afar	611	559	459	694	629	788	854	734	862	1002
Amhara	790	773	670	683	803	938	1045	915	980	955
Oromiya	635	594	572	659	764	1066	1035	916	851	954
Somali	885	756	867	735	767	1139	1032	775	723	957
BenishangulGumuz	737	684	697	780	884	1099	1113	1297	1147	978
SNNP[b]	493	494	480	531	597	735	808	671	656	755
Gambella	492	722	614	683	532	735	864	993	834	740
Harari	599	717	622	862	866	1185	1318	974	971	1525
Addis Ababa	1092	1041	933	1307	1048	1147	1361	1341	1136	1127
Dire Dawa	685	698	612	846	903	774	984	938	1034	1005
National average	697	686	633	695	756	935	989	883	856	902
	Growth rate in regional average real prices									
	2002	2003	2004	2005	2006	2007	2008	2009	2010	Average
Tigray	11.3	-15.6	6.5	-4.7	-3.5	7.5	-4.7	-5.0	-10.3	-2.1
Afar	-8.5	-17.9	51.0	-9.3	25.2	8.4	-14.1	17.5	16.3	7.6
Amhara	-2.1	-13.3	1.8	17.7	16.8	11.5	-12.4	7.0	-2.5	2.7
Oromiya	-6.5	-3.7	15.2	15.9	39.5	-2.9	-11.5	-7.0	12.1	5.7
Somali	-14.6	14.7	-15.3	4.4	48.5	-9.4	-24.9	-6.8	32.4	3.2
Benishangul-Gumuz	-7.2	1.8	12.0	13.4	24.3	1.3	16.5	-11.5	-14.7	4.0
SNNP	0.4	-2.9	10.7	12.3	23.1	9.9	-16.9	-2.3	15.1	5.5
Gambella	46.7	-15.0	11.4	-22.2	38.2	17.5	15.0	-16.0	-11.3	7.1
Harari	19.6	-13.3	38.5	0.5	36.9	11.2	-26.1	-0.3	57.0	13.8
Addis Ababa	-4.7	-10.3	40.0	-19.8	9.4	18.7	-1.5	-15.2	-0.9	1.7
Dire Dawa	1.9	-12.3	38.3	6.8	-14.3	27.1	-4.6	10.2	-2.8	5.6
National average	-1.5	-7.9	9.9	8.8	23.6	5.8	-10.7	-3.0	5.4	3.4

Source: Calculated from CSA data.

Notes: a) Nominal prices deflated using monthly consumer price indices.

b) SNNPR stands for Southern Nations Nationalities and People.

Oxen prices

Most trade in oxen occurred between farmers themselves. The fact that this category of cattle is used for draught power added with their maturity made them relatively more expensive. Nationwide, real prices of oxen of ages 4 and older averaged 1,570 birr and grew annually at a rate of 3.5 percent during the period. Prices ranged from the lowest 1,168 birr in 2003 to the highest 1,651 in 2007. Addis Ababa had the most expensive oxen markets with an average real price of 2,500 birr. The slightly faster growth in real prices of bulls observed during the 2005-2010 period is not observed for oxen, although the same pattern holds for nominal prices.

The rates at which real prices of bulls grew during the 2001-2011 period, 3.5 percent, was remarkably similar to the rate at which real prices of oxen grew, 3.4 percent. As we shall see in our econometric analysis interregional bulls markets are relatively better integrated, as this category of cattle are often destined to excess demand areas. This may imply that prices of bulls are largely driven by increased demand from urban centers. We also noted that a large amount of trade in cattle occurred amongst farmers, who mostly use older cattle for draught power. The joint implication of this is that increased demand for draught power played an equally important role for increased cattle prices as increased demand from urban area markets.

In addition to local conditions, international prices and other factors may influence cattle prices. Bachewe and Headey (forthcoming) found that out of the 2.5 percent average monthly growth in real cattle prices 0.8 percent was accounted for by increases in exports of live animals and meat while 0.2 percent resulted from increases in global prices. Consequently, the results of this later study highlight the reason behind some of the anomalous findings discussed in section 4 of this study. Moreover, it is possible that cattle prices in some of the regions, particularly markets in border towns, may be integrated with neighboring country prices and may largely respond to such prices. However, we could not investigate the effect of such prices as well as conduct market integration analyses as we do not have data with spatial and temporal dimensions aspects useful for such analyses. Bachewe and Headey make an effort to control for cross border trade using Northern Somalia cattle prices. However results of the analyses indicate that Northern Somalia prices are negatively related with cattle prices in Ethiopia.

Table 2: Regional average annual real prices of oxen.[a]

	Year									
Region	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Tigray	1582	1475	1168	1257	1234	1483	1651	1511	1458	1499
Afar	965	1010	896	1392	1341	1464	1505	1568	1722	1806
Amhara	1385	1388	1221	1287	1443	1758	2001	1704	1676	1610
Oromiya	1356	1369	1306	1464	1566	1961	2032	1894	1721	1867
Somali	1291	1540	1811	2064	2216	2363	2062	1752	1974	2340
Benishangul Gumuz	1187	1145	1157	1337	1455	1659	1676	1883	1702	1531
SNNP[b]	1057	1065	1065	1137	1310	1662	1725	1527	1468	1536
Gambella	1481	1524	1322	1547	1125	1719	1314	1645	1622	1656
Harari	1391	1504	1662	1968	2424	2504	2606	2226	2164	2904
Addis Ababa	2055	2098	2044	2319	2364	2398	2776	2993	3026	2899
Dire Dawa	1688	1675	1763	2253	2337	2459	2690	2470	1828	2456
National average	1323	1323	1251	1379	1497	1808	1920	1767	1687	1746

	Growth rate in regional average real prices									
	2002	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**Average**
Tigray	-6.8	-20.8	7.6	-1.8	20.2	11.3	-8.5	-3.5	2.8	0.1
Afar	4.6	-11.3	55.3	-3.7	9.2	2.8	4.2	9.9	4.8	8.4
Amhara	0.2	-12.1	5.4	12.1	21.8	13.8	-14.8	-1.7	-3.9	2.3
Oromiya	1.0	-4.6	12.1	7.0	25.2	3.6	-6.8	-9.1	8.5	4.1
Somali	19.2	17.6	13.9	7.4	6.6	-12.7	-15.1	12.7	18.6	7.6
Benishangul Gumuz	-3.5	1.0	15.5	8.9	14.0	1.0	12.4	-9.6	-10.0	3.3
SNNP	0.8	0.0	6.7	15.3	26.9	3.8	-11.5	-3.8	4.6	4.7
Gambella	2.9	-13.3	17.0	-27.3	52.8	-23.6	25.2	-1.4	2.1	3.8
Harari	8.1	10.5	18.4	23.2	3.3	4.1	-14.6	-2.8	34.2	9.4
Addis Ababa	2.1	-2.6	13.5	1.9	1.5	15.7	7.8	1.1	-4.2	4.1
Dire Dawa	-0.8	5.2	27.8	3.8	5.2	9.4	-8.2	-26.0	34.3	5.6
National average	-0.1	-5.4	10.3	8.6	20.8	6.2	-8.0	-4.5	3.5	3.5

Source: Calculated from CSA data.

Notes: a) Nominal prices deflated using monthly consumer price indices.

b) SNNPR stands for Southern Nations Nationalities and People.

In an attempt to set the scene for the econometric analysis this section provided an overview of cattle production, marketing, extent of commercialization, and trends in cattle prices. In the following section we describe the threshold autoregressive model used in the analysis.

Threshold autoregressive model

Even if sometimes used interchangeably, it is important to define the distinct concepts of spatial market integration and efficiency. Negassa and Myers (2004) define spatial market efficiency as an equilibrium condition whereby all potential profitable spatial arbitrage opportunities are exploited. Market efficiency is concerned on whether the optimal amount of trade is occurring. Two markets with positive trade volume of a homogenous good are spatially efficient if the price spread between them is equal to transfer costs. Without trade, the markets are spatially efficient only if the price differential is less than transfer costs. However, if the spatial price differential is greater than transfer cost the market is inefficient either with or without trade.

Spatial market integration is defined as tradability or contestability between markets, necessitating the transfer of Walrasian excess demand from one market to another, manifest in the physical flow of a commodity, the transmission of price shocks from one market to another, or both (Barrett and Li 2002). The authors also indicate that positive trade flows between two spatially distinct markets is sufficient but not necessary for some degree of spatial market integration. This is because if the regions belong to a common trading network then price shocks may be transmitted indirectly through the network (Fackler and Goodwin 2001). Markets that are not well integrated may transmit inaccurate price information that distorts marketing decisions and contributes to inefficient product movements (Goodwin and Schroeder, 1991).

Earlier works that studied market integration relied on methods that investigate co-movement of prices without examining transportation and arbitrage related issues and most importantly ignore the important role of transfer costs. Recent works that use time-series econometrics involving Granger causality, error-correction, and cointegration analysis may erroneously identify well functioning markets as lacking efficiency and provide no information about transfer costs. Such problems are rectified by the parity bounds model (PBM), if time-series data of transfer costs and trade flows were available, along with price data. PBM explicitly recognizes the effect of transaction costs in spatial integration of markets and uses endogenous switching models. However, data on transfer costs, which includes transportation and handling costs, and profit margin of middlemen, required to apply PBM are hard to come by, particularly in such a developing country as Ethiopia. As a result, in this study we use the threshold autoregressive model, which is a competing approach to PBM, to investigate market integration and efficiency along the lines indicated above.

The virtue in TAR models is not only they acknowledge the existence of transaction costs but also they provide estimates of thresholds that such transaction costs must exceed before price differentials start to adjust. The self-exciting threshold autoregressive model (SETAR) is used in this work. The SETAR is a TAR where the transition between thresholds depend on the lag of the price difference process itself. The specific version of SETAR used, due to Van Campenhout (2007) allows for time varying thresholds resulting from transaction costs that change over time. This provides a better measure of market integration relative to others that fix thresholds.

Suppose the difference in prices of two spatially segregated cattle markets i and j at time t is defined as $m_t \equiv p_t^i - p_t^j$. Depending on data availability, time is an appropriately defined duration, mostly, weekly and monthly data are used.. We are interested in establishing how the price difference at time t responds to the one in time t-1. That is,

$$\Delta m_t = \rho m_{t-1} + \varepsilon_t \qquad (1)$$

Where $\Delta m_t = m_t - m_{t-1}$ and ε_t is the error term distributed normally as $\varepsilon_t \sim N(0, \sigma^2)$. Price data from markets i and j are used to estimate ρ , which measures the speed at which price differences arising from price shocks in one or both markets adjust to an equilibrium condition, in which price differences are equated with transaction costs. A critical assumption implicit in specification is that the markets are competitive. More on this and other caveats at the end of the section.

As it stands the model given by (1) assumes that price differentials linearly adjust between the two periods, ignoring the non-linear effects introduced by transaction costs. The TAR model accounts for the nonlinear adjustment of price differentials introduced by transaction costs. According to TAR price differentials start to adjust when they exceed certain thresholds. The particular type of TAR model used in the analysis is

$$\Delta m_t = \begin{cases} \rho_{out} m_{t-1} + \varepsilon_t & m_{t-1} > \theta \\ \rho_{in} m_{t-1} + \varepsilon_t \quad if & -\theta \le m_{t-1} \le \theta \\ \rho_{out} m_{t-1} + \varepsilon_t & m_{t-1} < -\theta \end{cases} \tag{2}$$

Acknowledging the existence of thresholds results in estimating two parameters: a rate of adjustment where price differentials are within the threshold (ρ_{in}) and the other where price differentials exceed the threshold (ρ_{out}). According to the theory behind this approach, if price differentials are within this threshold of transaction costs, given by θ, adjustment does not take place, which implies that the best guess of price difference at time t is the price difference at time t-1. This characteristics enables impose unit root assumption on price differential by setting $\rho_{in} = 0,$ which helps increase identification of estimated parameters. Using this assumption Equation (2) can be restated as

$$\Delta m_t = \begin{cases} \rho_{out} m_{t-1} + \varepsilon_t & m_{t-1} > \theta \\ \varepsilon_t \quad if & -\theta \le m_{t-1} \le \theta \\ \rho_{out} m_{t-1} + \varepsilon_t & m_{t-1} < -\theta \end{cases} \tag{3}$$

One of the shortcomings of model (3) is its restrictive assumption of constant thresholds, in effect assuming transaction costs remain constant over the study period. One way of rectifying this is to define the threshold, θ, as some function of time, θ_t, as

$$\theta_t = \theta_0 + \frac{\theta_T - \theta_0}{T} * t \tag{4}$$

During the study period $t \in (0,T)$, $\theta_t = \theta_0$ at t=0, $\theta_t = \theta_T$ at t=T, and takes intermediate values, θ_t, depending on t. θ_0 and θ_T are identified through a grid search over possible candidates that selects a pair that minimize the sum of squared residuals.

The calculated thresholds resulting from the grid search are values in birr that price differentials should exceed before adjustment starts. As such they do provide no information about their value relative to prices of cattle in the two markets. In this work we introduce relative threshold values by dividing estimated thresholds by average prices of the two markets. This makes clears the relative importance of transaction costs in cattle prices.

Introducing a time trend that takes into account changes in the speed of adjustment over the study period makes the model more flexible. With this change the model can be rewritten as

$$\Delta m_t = \begin{cases} \rho_{out} m_{t-1} + \rho'_{out} * t * m_{t-1} + \varepsilon_t & m_{t-1} > \theta_t \\ \varepsilon_t & if \quad -\theta_t \leq m_{t-1} \leq \theta_t \\ \rho_{out} m_{t-1} + \rho'_{out} * t * m_{t-1} + \varepsilon_t & m_{t-1} < -\theta_t \end{cases} \qquad (5)$$

The rate of adjustment of price differentials at time t for differences in time t-1, given by ρ_{out} characterizes if the two markets are integrated and how fast prices adjust in integrated markets. In particular, an estimate of $\rho_{out} < 0$ indicates a narrowing price differential in the two markets at time t from its level at time t-1, which is taken to be a sign of integration of the two markets while $\rho_{out} > 0$ is an indication of non-integration. Efficiency of integrated markets is gauged by the magnitude of ρ_{out}, whereby a value of $\rho_{out} < -1$ represents adjustment at time t that exceeds price differentials in time t-1. That is, the adjustment made to the price differential at time t exceeds the differential that occurred at time t-1. Given that the price shock at time t-1 is assumed to have caused disequilibrium in price differential, the over-adjustment that followed also has the same effect. Since the resulting price differential following the over-adjustment exceeds transaction costs it implies the existence of inefficiency in the way the two markets are integrated.

The estimated ρ_{out} can also be used to calculate what is called a half-life of adjustment. A half-life is the time that is needed for a given price shock to return to half its initial value or it is $m_{t+h} = m_t/2$. It is calculated from the equation $h = \ln(0.5)/\ln(1+\rho)$, where by h denotes half-life. As a result, for over-adjusting markets with values of $\rho_{out} < -1$ prices adjust instantaneously. In such cases the denominator in the last expression is undefined, which is taken to mean adjustment is instantaneous. In efficiently integrated markets the values represent the period, in our case months, it takes to get to half of the initial price shock. Next we provide some of the caveats of the model relevant to this study.

Caveats

An important assumption implicit in such models is markets are perfectly competitive. Legese et. al.(2008) indicate that the level of competition in livestock markets in Ethiopia is not clearly known. Without information on the extent and type of imperfection, its consequence on prices and estimated thresholds cannot be judged. Upon making this inescapable assumption we make relevant points if indeed imperfections exist. Suppose there exist traders with market power; then integrated market pairs where such traders operate may be inefficient as price differentials exceed transaction costs, for the former likely include excessive profit margins resulting from imperfect pricing. Added with this, price shocks may transmit relatively faster or slower, depending on their effect on profit margins, as oligopolies face relatively less competition to adjust prices. Market imperfections arise also from changes in government policy and transportation bottleneck, which have been changing during the period under consideration. Consequently, interpretation of results of the analysis should consider the type of imperfection, its effect on prices, and the extent of distortion on agents' behavior.

By construction, the model identifies integrated market pair when prices in one adjust for price shocks in the other or when prices adjust for a shock simultaneously affecting both markets. As such, markets, which respond to common shocks, such as increased transportation costs, but not integrated through transmission of price shocks *between* them, could be identified as integrated. Some results presented in section 4 serve elaborate this point. Some data issues that become a concern due to the specific nature of the analysis are discussed below.

Unlike cointegration analysis and other earlier methods, the SETAR model accommodates both stationary and non-stationary price series as it uses price differences as its major input. We provide stationarity tests of the monthly price series of each of the 50 selected markets in Appendix 1. Averaged through the three models used, about 44 percent of the markets are non-stationary. We conducted the same test for the 1,225 price differences formed from the 50 market price series. Markets with non-stationary price differences may erroneously be identified integrated for price differences have some trend. Fortunately, only 1 and 7 are non-stationary in bulls and oxen markets by any of the 3 criteria. Out of the 7 non-stationary pairs in oxen markets only 4 are integrated; as a result almost all of the findings are free from this problem.

Number of missing observations becomes even more problematic in market integration analysis as data points missing in either or both markets are considered missing. However, considering the original data that included many markets that miss considerable number of observations, (Appendix 1) the problem was not severe. This is true particularly in oxen, which had 70 percent of the price differences with 90 or more of the 115 observations while this number was only 43 percent in bulls.

Among factors that make comparing results of analysis across cattle types difficult is the extent of variation in prices relative to their average value, as markets with relatively larger variation will appear less integrated. The numbers in Appendix 1 imply that standardized average bulls and oxen prices are almost equal. In an average market, both prices and standard deviation of prices of oxen were about twice as large as the respective values for bulls, with slightly less variation implied in oxen markets. The ration of standard deviation to average prices was 0.6 in an average bulls market while it was 0.56 in oxen markets, which implies 5 percent less variation in prices relative to average price in oxen than in bulls markets. This in turn slightly favors integration in oxen prices than in bulls; however, this factor seems to play little role in results of the analysis, as we shall see in the following section.

4. Results and Discussion

We select 50 markets for both bulls and oxen using number of observations in a market as a criterion. Number of observations in markets selected range from 67/71 in Kemashi/Wolkite for bulls/oxen to many markets with complete data (Appendix 1).[97] For administrative zones with many markets the market with the largest number of observations is selected. Some administrative zones are not represented by any market. Accordingly, 5, 9, 12, 5, and 9 markets were selected from Tigray, Amhara, Oromia, Benishangul-Gumuz, and SNNP, respectively, while the remaining 10 were from 5 other regions. Appendix 2 shows the location of the markets, their administrative regions, and connecting roads while Appendix 3 indicates their location relative to the 5 agro-ecologic zones of Ethiopia.[98]

[97] Appendix 1 contains information relevant to the econometric analysis.
[98] We are immensely indebted to Mekamu Kedir at EDRI for providing several versions of these maps.

Out of the 1,225 pairs formed from these markets we limit our discussion to 343 put into 4 groups.[99] The first group pairs markets in each region and comprises 80 pairs. Almost all intraregional market pairs are included in this group. However, as the markets in Amhara, Oromia, and SNNP are located in 2 geographically distinct clusters, roughly located in eastern and western parts of each region, results of analysis of market pairs in each cluster are presented and discussed. The second group pairs geographically close interregional /agro-ecologic zone markets. We included 69 pairs believed to capture interregional marketing routes. All markets located in areas with population size of at least 5,000 were used to form the third group of 190 pairs. In the fourth group all 49 markets are paired with the Kotebe market in Addis Ababa, which has the largest number of observation of the 2 in Addis Ababa. Summary of results and discussions pertaining intra and interregional bulls and oxen markets are presented in subsection 4.1. Results of these analyses are presented in Appendices 4 through 7. The latter two categories are summarized in subsection 4.2 while the results are presented in Appendices 8 through 11.

4.1 Results of analysis: intraregional and interregional markets.

Five observations can be made about results of integration analysis of intraregional and interregional markets, with exceptions in each group and animal type. First, as expected, geographically close intraregional markets are more often integrated than those farther apart. Secondly, a large number of intra and interregional market pairs are integrated in both cattle types than in only one. Moreover, excluding some peculiar pairs, price differentials adjust relatively similarly in both cattle markets and whether the markets are integrated in only one or both cattle price. Third, more interregional markets are integrated in bulls prices than in oxen. This supports the finding in section 2 that three-quarters of cattle are traded amongst farmers that mostly purchase oxen locally while bulls, mostly destined for end-consumption, cross regional boundaries along markets whose prices are integrated more frequently, which is corroborated also by the next observation. Fourthly, more interregional markets are integrated in only bulls prices than in oxen. Finally, the results imply improvements in marketing infrastructure and

[99] Note that the number of pairs discussed is larger than considered in almost all empirical studies that examine similar issues, most of which include only a handful of markets.

information as nationwide as well as regional average relative threshold values declined significantly in both categories and cattle types.[100]

Out of the 80 intraregional market pairs 63 percent were integrated in oxen and bulls prices (Table 4). Regionally, rates of integration in bulls prices ranged from 31 percent in Amhara to 90 percent in SNNP. Amhara performed worse also in oxen followed by SNNP, which performed superior in bulls. Hoe culture that dominates SNNP may explain the relatively low integration in oxen prices. Tigray region markets performed superior in oxen prices, closely followed by those in Oromia.

Table 4: Summary statistics integrated intraregional markets.

Region	Number of market pairs	Percent integrated	Average value of coefficient	Beginning threshold (percent of average price)	End threshold (percent of average price)	Proportion among integrated with instantaneous adjustment	Average coefficient of those with instantaneous adjustment
	Bulls markets						
Ethiopia	80	63	-1.534	92	18	40	-2.337
Tigray	10	50	-1.247	68	25	10	-1.810
Amhara	16	31	-1.94	77	21	13	-3.041
Oromia	23	57	-1.339	113	17	9	-2.365
SNNP	21	90	-1.602	103	18	52	-1.936
Others	10	80	-1.619	55	15	20	-4.076
	Oxen markets						
Ethiopia	80	63	-1.207	61	16	36	-2.110
Tigray	10	80	-1.152	29	12	10	-3.074
Amhara	16	44	-1.803	64	17	31	-2.132
Oromia	23	74	-1.167	66	16	9	-2.145
SNNP	21	48	-1.128	82	20	14	-1.728
Others	10	80	-0.924	55	13	0	-

Source: Analysis conducted using CSA data.

Recall that a coefficient of integration significantly less than -1 indicates inefficiently integrated markets. Among integrated bulls and oxen markets adjustment was instantaneous, with average coefficients significantly less than -1. However, these averages were dominated by the large number of pairs with coefficients significantly less

[100] Recall that we use beginning and end of period threshold values, $\theta_{t=1}$ and $\theta_{t=T}$, obtained from the analysis, to calculate the relative value of thresholds to the average price of cattle in market pairs considered during the respective periods.

than -1. Excluding such pairs coefficients of adjustment averaged -1 and -0.94 in bulls and oxen markets, respectively, which indicates there is a room for improvement in markets excluded from these calculations. This and the average coefficients of pairs with less than -1 imply that markets integrated in each cattle price performed similarly in efficiency.

Out of the 80 intraregional pairs the largest proportion were integrated in both prices followed by those integrated in only bulls or oxen prices (Table 5). Market pairs in most regions were more frequently integrated in both animal types, except in Tigray, where more markets are integrated in oxen prices only and in SNNP, where most integrated in bulls prices. Two of the 3 pairs in Somali and the Aysaita-Melka Werer pair in Afar are integrated in both cattle type, perhaps due to the large magnitude of cattle trade in these pastoralist areas.

Table 5: Summary statistics of intraregional markets integrated in either or both bulls and oxen markets.

Region	Cattle type	Number integrated	Percent integrated	Average value of coefficient	Beginning threshold (percent of average price)	End threshold (percent of average price)
National average	Bulls	18	23	-1.742	99	22
	Oxen	18	23	-1.330	55	14
	Both	31	39	-1.277	75	17
Tigray	Bulls	2	20	-1.016	47	21
	Oxen	5	50	-0.937	25	11
	Both	3	30	-1.455	59	21
Amhara	Bulls	1	6	-1.176	98	39
	Oxen	3	19	-2.294	66	20
	Both	4	25	-1.783	67	16
Oromia	Bulls	3	13	-1.320	105	18
	Oxen	8	35	-1.381	66	14
	Both	10	43	-1.211	89	17
Afar and Somali	Bulls	0	0	_	_	_
	Oxen	0	0	_	_	_
	Both	3	75	-0.887	61	19
Benishangul-Gumuz	Bulls	1	17	-6.510	113	26
	Oxen	1	17	-0.947	76	10
	Both	4	67	-0.894	31	9
SNNP	Bulls	11	52	-1.607	106	21
	Oxen	1	5	-0.390	63	18
	Both	8	38	-1.378	96	18

Source: Analysis conducted using CSA data.

On average the speed of adjustment was the fastest when markets are integrated in bulls prices, due to the relatively larger number of instantaneously adjusting pairs in bulls prices and driven by few extremely inefficiently integrated pairs in Benishangul-Gumuz (BG) and SNNP. Excluding the two regions coefficients of adjustment averaged -1.2, -1.4, and -1.3 in markets integrated in only bulls, only oxen, and in both bulls and oxen prices. Again, implying that integrated market pairs were relatively similar in their efficiency whether they are integrated in only one or both cattle prices.

Eighteen percent more interregional bulls markets are integrated, relative to the 46 percent oxen markets, which is consistent with more bulls crossing regional boundaries (Table 6). Cross-regional rates of integration in bulls prices ranged from the lowest between Tigray and Afar to the largest between Oromia and SNNP. The reverse was true for oxen with those in Tigray and Afar performing superior and those in Oromia and SNNP least integrated.

Table 6. Summary statistics of integrated interregional markets.

Region	Number of market pairs	Percent integrated	Average value of coefficient	Beginning threshold (percent of average price)	End threshold (percent of average price)	Proportion integrated with instantaneous adjustment	Average coefficient with instantaneous adjustment
	Bulls markets						
Ethiopia	69	64	-1.2821	74	15	14	-2.11
Tigray[a]	6	33	-1.458	82	9	17	-2.111
Amhara[b]	19	63	-1.4822	70	16	16	-2.806
Oromia[c]	29	59	-1.0011	54	14	0	-
SNNP[d]	15	87	-1.5365	106	17	40	-2.113
	Oxen markets						
Ethiopia	69	46	-1.338	65	13	13	-2.079
Tigray[a]	6	83	-1.817	103	14	50	-2.59
Amhara[b]	19	42	-1.718	79	17	21	-2.294
Oromia[c]	29	48	-1.189	57	12	7	-1.92
SNNP[d]	15	33	-0.934	42	11	0	_

Notes: a) Tigray with Afar,

b) Amhara with Afar , Oromia, and Benishangul-Gumuz,

c) Oromia with Benishangul-Gumuz, Gambella, Somali, and others

d) SNNP with Oromia

Source: Analysis conducted using CSA data.

Integrated interregional bulls markets were slightly more efficient relative to oxen. Again these averages were dominated by pairs with extremely large coefficients. Excluding 4 and 3 coefficients with values less than -2.5, interregional market pairs coefficients of integrated bulls and oxen markets averaged -1.14 and -1.23, respectively. Almost equal proportion of markets integrated in bulls and oxen prices has coefficients significantly less than -1 while coefficients of these pairs averaged about the same,-2.1.

Relative to intraregional markets slightly more pairs were integrated in only bulls prices at 29 percent, slightly less pairs were integrated in both cattle prices at 35 percent, while the proportion integrated in only oxen prices was significantly lower (Table 7). Markets integrated in only bulls prices were relatively more efficient with average coefficient of -1.23 relative to those integrated in only oxen and in both prices. Again, these averages were dominated by few large coefficients; excluding the single smallest coefficient from pairs integrated in only bulls, oxen, and in both prices drops the averages to -1.14, -1.1, and -1.33. Patterns in rates and average coefficients observed for the aggregate sample held across regions, with some exceptions.

Table 7: Summary statistics of interregional markets integrated in either or both bulls and oxen markets

Region	Cattle type	Number integrated	Percent integrated	Average value of coefficient	Beginning threshold (percent of average price)	End threshold (percent of average price)
Ethiopia	Bulls	20	29	-1.226	100	19
	Oxen	8	12	-1.317	65	10
	Both	24	35	-1.391	62	14
Tigray[a]	Bulls	0	0	_	_	_
	Oxen	3	50	-1.430	74	6
	Both	2	33	-1.928	114	17
Amhara[b]	Bulls	6	32	-1.013	77	18
	Oxen	2	11	-1.795	49	6
	Both	6	32	-1.822	76	17
Oromia[c]	Bulls	6	19	-1.048	70	14
	Oxen	3	10	-0.886	66	15
	Both	11	35	-1.123	50	13
SNNP[d]	Bulls	8	53	-1.520	139	23
	Oxen	0	0	_	_	_
	Both	5	33	-1.249	48	10

Notes: a) Tigray with Afar,
b) Amhara with Afar , Oromia, and Benishangul-Gumuz,
c) Oromia with Benishangul-Gumuz, Gambella, Somali, and others
d) SNNP with Oromia
Source: Analysis conducted using CSA data.

In integrated intraregional bulls and oxen markets, relative values of thresholds declined nationwide by 72 and 62 percent during the 2001-2011 period (annually, the decline averaged 8 and 6.9 percent) while the decline was 68 percent (7.5 percent annually) in both integrated interregional bulls and oxen prices. The nationwide decline was also observed across regions, cattle types, and market groups, which differed only in degrees thresholds declined. In integrated large population area markets and those paired with Addis Ababa, relative thresholds declined by 66 and 80 percent during 2001-2011 (7.4 and 8.9 percent annually) in bulls markets and by 68 and 64 percent (6.7 and 7.2 percent annually) in oxen markets.

The decline in relative thresholds resulted from the fast growth in average prices with little change in threshold values. Bulls and oxen prices of integrated intraregional, interregional, large-population-area, and markets paired with Addis Ababa-Kotebe grew at average monthly rates of 3.5, 3.8, 3.5, and 2.6 percent. By contrast, threshold values of the respective groups grew monthly at rates of 0.46, 0.52, 0.63, and 0.09 percent and represented only 13, 14, 18, and 3 percent of the growth in cattle prices. The relatively slow growth in nominal threshold values, which in real prices declined monthly at 0.5 percent among the 8 group-animal types, may in turn have resulted from the unprecedented increase in rural road constructed and mobile and wireless telephone services that targeted rural residents.

4.2 Results of analysis: Integration between large population areas and with Addis Ababa.

Twenty regional markets located in areas with population of 5,000 or more were paired to form the third group of 190 pairs. We provide results of the 145 in Appendices 8 and 9, dropping the 45 included in intra or interregional groups. Results of the 49 markets paired with the Kotebe market in Addis Ababa are given in Appendices 10 and 11. We use results of integration analysis of the 48 regional markets with Akaki when necessary. The fact that most large population area (LPA) markets serve both as end-user and collection centers for downstream markets justifies forming the third group. Investigating integration of regional markets with Addis Ababa is important as it constitutes the largest excess demand area supplied by most marketing route in the country.

Out of the 145 market pairs in LPAs 76 were integrated in bulls prices while 73 were integrated in oxen prices (Table 8). Awassa and Bahir Dar were integrated with most markets they were paired with in bulls prices while Nazareth and the group of smaller city market pairs named “Others” were least integrated. Awassa was frequently and efficiently integrated in both bulls and oxen prices, along with Mekelle in oxen. Dire Dawa is the least integrated in oxen prices, followed by JigJiga and Gambella. Observations made when comparing results using bulls and oxen prices include the following. Large population area markets are more often integrated in bulls than in oxen, except Mekelle, Ayasaita and the group of markets in relatively smaller population. Moreover, price differentials adjust relatively faster in the animal type a given market is more frequently integrated in, with some exceptions.

Table 8: Summary statistics of integrated markets in large population areas.

Area	Number of market pairs	Percent integrated	Average value of coefficient	Beginning threshold (% average price)	End threshold (% average price)	Proportion instantaneously adjusting (%)	Average coefficient of instantaneously adjusting
	Bulls markets						
All pairs	145	52	-1.438	70	14	10	-3.25
Dire Dawa	16	44	-3.431	91	10	38	-3.48
Nazareth	15	33	-1.507	79	11	7	-2.98
Bahir Dar	13	85	-2.225	85	15	5	-3.41
Mekelle	12	50	-0.942	50	15	0	_
Awassa	12	100	-1.068	91	14	0	_
Harar	12	83	-1.363	62	12	17	-2.32
Gondar	10	40	-0.707	24	7	0	_
Jigjiga	11	73	-0.747	67	17	0	_
Aysaita	6	50	-1.123	33	23	0	_
Gambella	8	50	-1.071	51	11	0	_
Others	30	20	-0.783	67	14	0	_
Border towns	105	63	-1.101	59.35	15.03	4.762	-2.444
	Oxen markets						
All pairs	145	50	-1.329	64	15	12	-2.31
Dire Dawa	16	0	_	_	_	_	_
Nazareth	15	33	-0.876	31	6	0	_
Bahir Dar	13	54	-0.943	67	13	0	_
Mekelle	12	83	-1.611	57	12	42	-2.23
Awassa	12	83	-0.882	25	9	0	_
Harar	12	67	-1.315	107	25	8	-1.87
Gondar	10	30	-0.959	53	11	0	_
Jigjiga	11	18	-0.407	137	33	0	-2.27
Aysaita	6	67	-2.083	90	20	50	-2.48
Gambella	8	25	-1.786	102	23	0	_
Others	30	73	-1.590	64	16	27	-2.36
Border towns	105	58	-0.918	69	19	2	-3.73

Source: Analysis conducted using CSA data.

The large average coefficients implied relatively inefficient integration. However, these averages were dominated by those paired with Bahir Dar and Dire Dawa for bulls, without which the coefficients averaged -1.05, by Aysaita and the 30 pairs in smaller population areas for oxen, without which the coefficients average -1.14, That only 14 of the 76 bulls and 17 of the 73 oxen price pairs have coefficients significantly less than -1 implies lower level of inefficiently integrated markets relative to those in intra and interregional market pairs.

Out of the 145 LPA market pairs 35, 32, 41, and 37 were integrated in only bulls, oxen, in both bulls and oxen, and in neither prices, respectively (Table 9). Similar with the last two categories relatively larger pairs are integrated in both cattle prices than in only one; however, average beginning of period relative threshold values of pairs integrated in both prices were larger than those integrated in only one, unlike in the previous two categories.

The two groups discussed in this subsection comprised markets paired without consideration for geographic proximity and supply and demand conditions, two conditions crucial for market integration. Consequently, we expected much lower pairs integrated than obtained in the results, which required investigation of each integrated pair relative to their location and other non-integrated markets. This revealed that some implied integrations cannot be explained by either of the justifications above. For instance, the market in Dire Dawa is integrated in bulls prices with markets as far as Chagni, Debre Markos, Bahir Dar, Jimma, and Metu without being integrated with Nazareth, though which the road connecting Dire Dawa and the previous markets passes. The same holds for Dire Dawa's integration with Awassa without being integrated to the closer market in Shashemene, making all of Dire Dawa's integrations in bulls prices suspect. Nazareth is integrated in bulls prices with as far markets as Mekelle, Debre Markos, Bahir Dar, and Jimma without being integrated with Addis Ababa. It is integrated with Harar and Jigjiga but not with Dire Dawa, and with Awassa but not with Shashemene; again making all integrations of Nazareth in bulls prices suspect. A similar look at implied integrations in bulls prices of the remaining pairs and in oxen prices make drawing conclusions from these pairs difficult.

We took this a step further by investigating if and how border-town markets, which are likely to be commonly affected by neighboring country and international prices, are integrated. The two lines at the end of each panel in Table 8 contain the summary. We select 3, 5, 4, and 3 markets close to the respective northern, eastern, southern, and western boundaries of Ethiopia. These 105 pairs are integrated efficiently at one of the largest rates even when only few are connected by marketing channels, are mostly as farther apart as the markets in the sample can be, and are mostly excess supply areas.

Table 9: Summary statistics of large population area markets integrated in either or both bulls and oxen markets

Region	Cattle type	Number integrated	Percent integrated	Average value of coefficient	Beginning threshold (% of average price)	End threshold (% of average price)
National average	Bulls	35	24	-1.609	63	12
	Oxen	32	22	-1.476	56	15
	Both	41	28	-1.253	74	15
Dire Dawa	Bulls	7	44	-3.431	91	10
	Oxen	0	0	_	_	_
	Both	0	0	_	_	_
Nazareth	Bulls	2	13	-0.730	34	14
	Oxen	2	13	-1.015	39	10
	Both	3	20	-1.405	68	6
Bahir Dar	Bulls	6	46	-2.210	67	15
	Oxen	2	15	-0.621	32	7
	Both	5	38	-1.657	94	15
Mekelle	Bulls	1	8	-0.661	7	2
	Oxen	5	42	-1.579	38	13
	Both	5	42	-1.320	67	15
Awassa	Bulls	2	17	-0.764	64	11
	Oxen	0	0	_	_	_
	Both	10	83	-1.006	61	12
Harar	Bulls	3	25	-1.442	74	14
	Oxen	1	8	-1.522	115	25
	Both	7	58	-1.307	82	18
Gondar	Bulls	4	40	-0.707	24	7
	Oxen	3	30	-0.959	53	11
	Both	0	0	_	_	_
Jigjiga	Bulls	6	55	-0.725	64	16
	Oxen	0	0	_	_	_
	Both	2	18	-0.609	106	28
Aysaita	Bulls	0	0	_	_	_
	Oxen	1	17	-2.679	89	15
	Both	3	50	-1.504	62	23
Gambella	Bulls	3	38	-1.150	65	13
	Oxen	1	13	-1.218	85	13
	Both	1	13	-1.594	65	18
Others	Bulls	1	3	-0.422	46	17
	Oxen	17	57	-1.633	60	17
	Both	5	17	-1.150	74	13

Source: Analysis conducted using CSA data.

In summary, while some features of integrated market pairs in LPAs conform to results of the previous groups, observations made in the last 2 paragraphs make it peculiar. A complete explanation of suspicious integrations requires investigation of patterns and causes of price movements in markets involved. Part of the explanation may lie in shocks that create co-movement of prices, as was found out by a follow-up of this study (Bachewe and Heady forthcoming). One of the findings of the study referred, covering the 2005-2011 period and most markets paired in this work is that increases in cattle prices were mainly driven by increased exports of live animals and meat exports, increased international meat prices, and domestic animal transportation and feed prices. Consequently, most of the pairs that appear integrated by transmission of price shocks through cattle traded between them may only have prices that respond similarly to shocks affecting both areas.

Table 10: Summary statistics of markets integrated with Kotebe in Addis Ababa.

Region	Number of market pairs	Percent integrated	Average value of coefficient	Beginning threshold (percent of average price)	End threshold (percent of average price)	Proportion integrated with instantaneous adjustment	Average coefficient with instantaneous adjustment
	Bulls markets						
Ethiopia	48	27	-0.6157	108	22	0	_
Tigray	5	40	-0.7126	75	8	0	_
Afar	2	0	_	_	_	0	_
Amhara	9	33	-0.5749	93	19	0	_
Oromia	12	8	-0.2526	72	27	0	_
Somali	3	33	-1.0684	96	8	0	_
Benishangul-Gumuz	5	20	-0.9087	227	67	0	_
SNNP	9	44	-0.4536	110	25	0	_
	Oxen markets						
Ethiopia	48	73	-0.779	105	30	2	-2.498
Tigray	5	100	-0.898	119	28	20	-2.498
Afar	2	50	-0.462	89	38	0	_
Amhara	9	67	-0.668	87	31	0	_
Oromia	12	83	-0.690	89	23	0	_
Somali	3	33	-1.092	165	25	0	_
Benishangul-Gumuz	5	80	-0.870	110	37	0	_
SNNP	9	67	-0.773	135	36	0	_

Source: Analysis conducted using CSA data.

As expected, a small proportion of regional markets are integrated with the Kotebe market in Addis in bulls prices. However, contrary to expectations, Kotebe is integrated with the largest proportion of markets in oxen prices. Regionally, proportion of integration in bulls prices ranged from no integration with Afar to 44 percent with SNNP while in oxen prices it ranged from the least with Somali to all 5 markets in Tigray. Unlike results of previous categories no price pair adjusted instantaneously in bulls and only 1 pair in oxen prices and average values of coefficients were significantly larger relative to the previous 3 groups. The peculiarities observed when pairing regional markets with Kotebe do not occur when pairing them with Akaki, which is integrated with only 27 and 35 percent of the pairs in bulls and oxen markets; however, this group had the smallest average estimated coefficient of -1.69 for bulls markets and one of the largest for oxen at -1.21.

The relatively larger proportion of markets integrated with Kotebe in only oxen prices we have in Table 11 derives from its large proportion of integration relative to bulls prices. However, this is observed also with Akaki, which was integrated with 11, 22, and 16 of the markets in only bulls, only oxen, and in both prices. In addition to Afar and Somali, each with 1 market integrated with Kotebe in only oxen prices, Tigray, Oromia, and Benishangul-Gumuz had no markets integrated with Kotebe in only bulls prices. This no or low integration in bulls prices relative to frequent integration in oxen prices contradicts previous observations and the claim made that bulls cross regional boundaries more often than oxen.

Explaining the peculiar results noted above and difference in rates and average coefficients of integration between the 2 Addis Ababa markets required a close look at each of the results. Such a comparison, which we did briefly for large population area markets, reveals equally peculiar implied integrations in both cattle types and markets. These details can be glanced from Appendices 10 and 11 together with the map in Appendix 2. Consequently, we derive no implications from results of integration analysis of regional markets with those in Addis Ababa.

Table 11: Summary statistics of markets integrated with Kotebe in Addis Ababa in either or both bulls and oxen markets

Region	Cattle type	Number integrated	Proportion integrated	Average value of coefficient	Beginning threshold (% of average price)	End threshold (% of average price)
National average	Bulls	2	4	-0.569	86	12
	Oxen	24	53	-0.683	96	30
	Both	9	20	-0.783	122	29
Tigray	Bulls	0	0	_	_	_
	Oxen	3	60	-0.660	115	25
	Both	2	40	-1.093	100	20
Amhara	Bulls	1	11	-0.796	91	8
	Oxen	4	44	-0.614	77	38
	Both	2	22	-0.621	101	20
Oromia	Bulls	0	0	_	_	_
	Oxen	9	75	-0.730	101	21
	Both	1	8	-0.368	62	33
Afar and Somali	Bulls	0	0	_	_	_
	Oxen	2	40	-0.771	93	31
	Both	0	0	-0.944	_	_
Benishangul-Gumuz	Bulls	0	0	_	_	_
	Oxen	3	60	-0.833	104	38
	Both	1	20	-0.944	177	52
SNNP	Bulls	1	11	-0.342	82	17
	Oxen	3	33	-0.496	86	40
	Both	3	33	-0.770	152	30

Source: Analysis conducted using CSA data.

This subsection presented integration analysis that paired 20 markets in large population areas and 48 regional markets with Addis Ababa. The result that conformed to previous categories notable is fall in relative threshold values. Others include declining proportion of integration as geographically distant markets are considered, with the exception of integration with Kotebe in Addis Ababa in oxen prices, and larger integration of markets in bulls relative to oxen in large population area markets. The previous 2 categories had some integrated pairs unexplainable through proximity or supply and demand conditions. However, the problem was widespread in the last two categories making most integrations suspect, which was also supported by results that paired border-town markets. As a result we conclude that implied integration of prices in these categories are at best consequences of co-movements of prices resulting from shocks affecting the markets jointly, as indicated in other studies, than price adjustments resulting from cattle trade between markets paired.

In summary, the following conclusions are derived from results of analysis by putting the 50 markets in 4 groups. While geographically close intra and interregional markets are more often integrated than those farther apart, they tend to be frequently integrated in both prices than in only one and integration in only bulls prices strengthens as cross regional markets are considered. Price differentials adjust relatively similarly in both cattle markets implying similarity in market efficiency. Moreover, relative threshold values declined significantly in all categories and cattle types. However, results of analysis that paired markets in large population areas and with Addis Ababa imply integrations or lack thereof among the pairs cannot be explained through transmission of price shocks but may only be attributed to factors affecting prices jointly.

5. Summary and Key Findings.

The issue of market integration and market efficiency are at the crux of policy debates aiming at market liberalization, pricing policy, and restructuring marketing institutions and infrastructure. Sustainable solutions to stabilize food prices should comprise the entire food value chain and its participants. This study is aimed at understanding the extent of integration of bulls and oxen markets and investigating efficiency of existing integration. The outcome of such an analysis is believed to inform researchers and policy makers on how well price changes are transmitted across markets, which in turn will help improve cattle marketing and commercialization, which is now only at its infancy.

Most of the cattle in Ethiopia are produced traditionally by mixed crop-animal farming and pastoralist households that raise the animals for other purposes than selling. The traditional nature is manifested not only by low level of adoption of modern animal production methods, but also by low rates of integration to inputs and output markets. Moreover, most households own few heads of cattle and low rates of productivity, which result in low commercial off-take rates. Commercializing production will provide an alternative source of income, expand supply, and improve quality.

This study applied threshold autoregressive (TAR) model on monthly prices data of 50 markets covering the July 2001-January 2011 period. CSA price data used in the analysis indicate that average regional and nationwide nominal and real prices have grown significantly during the 2001-2010 period and in particular, growth was faster during the 2005-2010 periods. Results of integration analyses conducted by pairing markets within regions and with close interregional markets imply that most markets are integrated; and integrations can be attributed to either proximity or to supply and demand factors. However, analyses that paired large population markets and all markets with Addis Ababa lead to no implication. The following general observations were made from results of the analysis.

Geographically close intra and interregional markets are more often integrated than those farther apart. Most intra and interregional markets integrated in both cattle prices than in only one and integration in only bulls prices strengthens as cross regional markets are considered. This implies that while most integrated markets specialize in both cattle types, interregional markets perform better in bulls. This supports the finding that most intraregional trade in cattle occurs amongst farmers that mostly purchase oxen locally while bulls, mostly destined for end-consumption, cross regional boundaries along markets whose prices are integrated more frequently. Moreover, integrated markets perform similarly in efficiency in both cattle markets and whether the markets are integrated in only one or both cattle prices. Finally, nationwide as well as regional relative threshold values declined significantly among all groups and cattle types. This may have resulted from improvements in physical infrastructures and improvement in marketing information.

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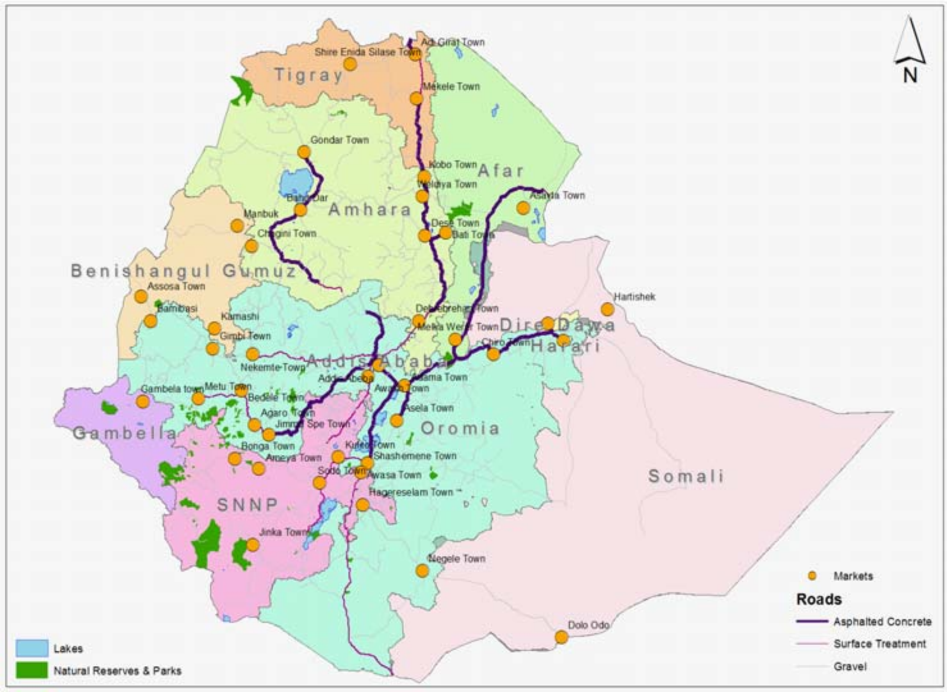
Appendix 1: Market level descriptive statistics and results of stationarity tests-July 2001-January 2011

Market	Bulls							Oxen						
	Descriptives			P-values of DF and Phillips-Perron stationarity tests of bulls prices				Descriptives			P-values of DF and Phillips-Perron stationarity tests of oxen prices			
	Mean price	Standard Dev.	Missing obs. (out of 115)	Augmented Dickey-Fuller		Phillips_Perron (lags(1) trend)	Percent stationary	Mean price	Standard Dev.	Missing obs. (out of 115)	Augmented Dickey-Fuller		Phillips_Perron (lags(1) trend)	Percent stationary
				No lag	Lag 1						No lag	Lag1		
Endaselassie	946	438	4	0.00	0.00	0.00	100	1963	1005	1	0.23	0.06	0.00	67
Axum	1080	391	8	0.00	0.03	0.00	100	1590	779	2	0.00	0.00	0.00	100
Adigrat	977	556	3	0.40	0.13	0.01	33	1706	911	2	0.31	0.07	0.00	67
Maichew	758	251	4	0.01	0.02	0.00	100	1264	360	5	0.05	0.02	0.00	100
Mekelle	1220	727	2	0.18	0.06	0.00	67	1847	1384	3	0.80	0.19	0.12	0
Aysaita	818	574	8	0.54	0.35	0.00	33	1710	1256	9	0.72	0.30	0.06	33
Melka_Werer	861	514	1	0.30	0.28	0.00	33	1604	908	2	0.08	0.16	0.00	67
Gondar	946	546	24	0.26	0.05	0.00	67	1863	1054	4	0.70	0.25	0.00	33
Kobo	776	406	1	0.43	0.08	0.00	67	1629	752	1	0.35	0.13	0.00	33
Woldia	885	450	0	0.63	0.28	0.10	33	1628	803	1	0.01	0.01	0.00	100
Dessie	945	581	3	0.17	0.34	0.00	33	1785	988	1	0.84	0.45	0.11	0
Debre_Birhan	1083	493	4	0.26	0.23	0.00	33	2258	1220	2	0.08	0.23	0.00	67
Debre_Markos	794	521	6	0.00	0.01	0.00	100	1545	796	1	0.00	0.01	0.00	100
Bahir_Dar	1015	695	4	0.61	0.42	0.08	33	2077	1140	2	0.41	0.20	0.00	33
Chagni	959	599	0	0.18	0.05	0.12	33	1717	962	2	0.19	0.06	0.08	67
Batti	1259	880	2	0.09	0.11	0.00	67	2096	986	1	0.28	0.13	0.00	33
Gimbi	689	308	3	0.34	0.30	0.00	33	1560	850	1	0.41	0.23	0.00	33
Nekemt	942	602	1	0.77	0.27	0.03	33	1977	1289	1	0.72	0.34	0.00	33
Bedele	774	446	3	0.07	0.12	0.00	67	1314	618	1	0.49	0.16	0.00	33
Metu	874	416	0	0.19	0.08	0.00	67	1481	624	0	0.20	0.11	0.00	33
Jimma	710	479	3	0.00	0.04	0.00	100	2049	1376	2	0.48	0.37	0.00	33

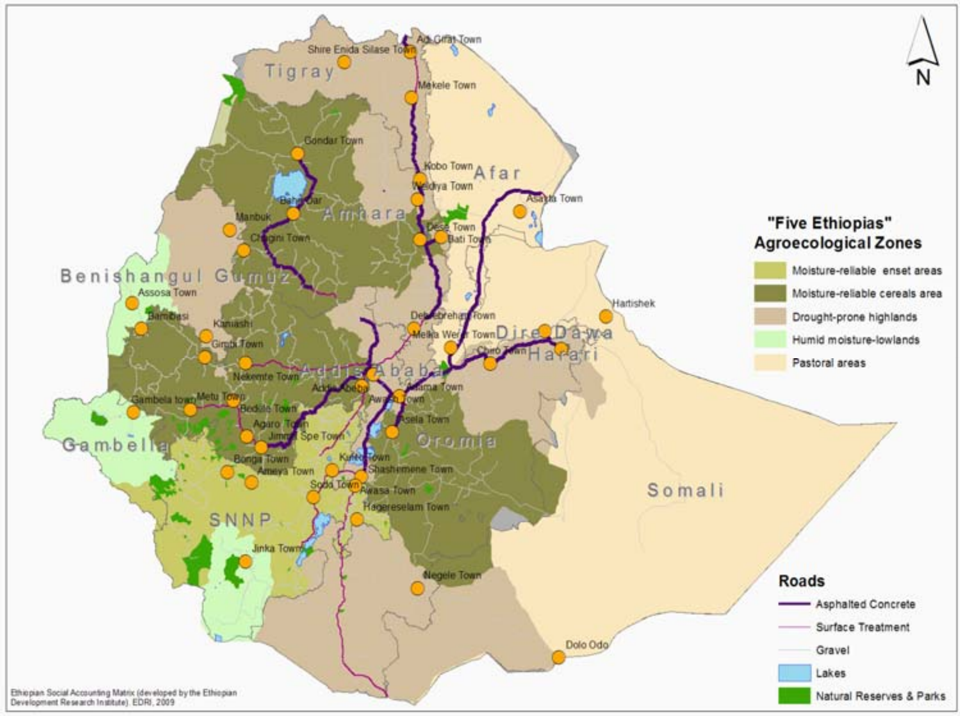
Market	Bulls							Oxen						
	Descriptives			P-values of DF and Phillips-Perron stationarity tests of bulls prices				Descriptives			P-values of DF and Phillips-Perron stationarity tests of oxen prices			
	Mean price	Standard Dev.	Missing obs. (out of 115)	Augmented Dickey-Fuller		Phillips_Perron (lags(1) trend)	Percent stationary	Mean price	Standard Dev.	Missing obs. (out of 115)	Augmented Dickey-Fuller		Phillips_Perron (lags(1) trend)	Percent stationary
				No lag	Lag 1						No lag	Lag1		
Agaro	869	626	4	0.40	0.26	0.00	33	1693	829	0	0.42	0.21	0.00	33
Nazareth	998	674	2	0.22	0.04	0.14	33	2121	1444	3	0.61	0.34	0.15	0
Shashemene	873	620	2	0.10	0.10	0.00	33	1619	898	1	0.36	0.14	0.00	33
Assela	708	404	1	0.03	0.01	0.00	100	1708	965	1	0.17	0.07	0.00	67
Assebe_Teferi	1231	789	1	0.25	0.30	0.00	33	2103	1166	1	0.41	0.23	0.00	33
Negele	1046	635	1	0.15	0.21	0.00	33	1353	526	2	0.04	0.07	0.00	100
Moyalle	926	607	20	0.00	0.00	0.00	100	1715	923	18	0.00	0.04	0.00	100
Jigjiga	1164	562	0	0.06	0.15	0.00	67	2621	993	1	0.03	0.04	0.00	100
Hartishek	935	551	0	0.13	0.24	0.00	33	2575	1625	1	0.54	0.34	0.02	33
Dollo	704	483	15	0.41	0.33	0.03	33	1193	678	31	0.16	0.03	0.01	67
Mambuk	1245	753	4	0.21	0.09	0.00	67	1950	1053	0	0.26	0.06	0.00	67
Mender_7	1304	924	4	0.07	0.03	0.01	100	1968	1148	5	0.47	0.06	0.17	33
Assosa	991	592	0	0.05	0.06	0.00	100	1647	978	0	0.26	0.09	0.00	67
Bambasi	962	513	2	0.33	0.09	0.00	67	1682	978	2	0.31	0.12	0.00	33
Kemashi	864	449	48	0.00	0.20	0.00	67	1420	816	5	0.26	0.03	0.00	67
Wolkite	503	245	43	0.88	0.18	0.37	0	1416	790	44	0.87	0.61	0.88	0
Hosaena	610	248	3	0.00	0.00	0.00	100	1909	1041	2	0.03	0.06	0.00	100
Alaba	802	603	4	0.00	0.02	0.00	100	1589	1011	3	0.17	0.03	0.02	67
Awassa	1267	1147	8	0.85	0.32	0.46	0	2161	1489	4	0.76	0.63	0.02	33
Hagere_Selam	574	252	2	0.99	0.87	0.20	0	1479	818	1	0.84	0.45	0.00	33
Wolayita_Sodo	827	645	5	0.86	0.52	0.20	0	1936	1431	3	0.27	0.07	0.00	67
Jinka	809	618	2	0.56	0.60	0.22	0	1966	981	2	0.02	0.02	0.00	100

Market	Bulls							Oxen						
	Descriptives			P-values of DF and Phillips-Perron stationarity tests of bulls prices				Descriptives			P-values of DF and Phillips-Perron stationarity tests of oxen prices			
	Mean price	Standard Dev.	Missing obs. (out of 115)	Augmented Dickey-Fuller		Phillips_Perron (lags(1) trend)	Percent stationary	Mean price	Standard Dev.	Missing obs. (out of 115)	Augmented Dickey-Fuller		Phillips_Perron (lags(1) trend)	Percent stationary
				No lag	Lag 1						No lag	Lag1		
Bonga	748	637	1	0.00	0.20	0.00	67	1366	782	1	0.87	0.60	0.03	33
Amaya	571	332	3	0.20	0.14	0.00	33	1209	686	2	0.02	0.03	0.00	100
Gambella	976	575	40	0.14	0.36	0.00	33	2122	1075	40	0.70	0.20	0.01	33
Harar	777	472	42	0.94	0.74	0.29	0	1724	880	42	0.06	0.04	0.00	100
AA_Kotebe	1010	441	11	0.02	0.07	0.00	100	2732	1551	3	0.01	0.02	0.00	100
AA_Akaki	1252	832	14	0.02	0.00	0.00	100	2697	1805	17	0.40	0.07	0.01	67
Dire Dawa	1136	778	34	0.06	0.07	0.00	100	2654	1586	31	0.01	0.00	0.00	100
Average/% stationary	920	557	8	38	44	84	55	1820	1020	6	30	50	90	56.67
Tigray	996	472	4	60	80	100	80	1674	888	3	40	80	80	67
Afar	840	544	5	0	0	100	33	1657	1082	6	50	0	100	50
Amhara	963	575	5	22	44	89	52	1844	967	2	33	33	89	52
Oromia	887	550	3	33	42	92	56	1724	959	3	17	25	92	44
Somali	934	532	5	33	0	100	44	2130	1098	11	33	67	100	67
Benishngul-Gumz	1073	646	12	60	80	100	80	1733	994	2	0	80	80	53
SNNP	746	525	8	33	22	44	33	1670	1003	7	33	56	89	59
Addis Ababa	1131	636	13	0	0	50	17	2714	1678	10	50	50	100	67

Appendix 2: Cattle markets selected relative to their respective administrative regions and roads in the country.



Appendix 3: Cattle markets selected for analysis in the 5 agroecologic zones of Ethiopia.



Appendix 4: Estimated results of TAR model with time varying thresholds, nominal price differences, intraregional bulls markets.

Market Pair	ρ	ρ*t	Beg. thr. (%)a	End thr. (%)a	Half Life	Market Pair	ρ	ρ*t	Beg. thr. (%)a	End thr. (%)a	Half Life
Endaselassie_Axum	-0.590**	-0.001	70	33	0.8	Aysaita_Melka_werer	-1.642***	0.012***	35	7	.
Endaselassie_Adigrat	-1.044***	0.006*	77	27	.	Gondar_Debre_Mark.	0.091	-0.010*	60	7	-8.0
Endaselassie_Maichwe	-0.988***	0.005	18	15	0.2	Gondar_Bahir_Dar	-2.500***	0.020***	87	21	.
Endaselassie_Mekelle	-1.805***	0.016***	57	38	.	Gondar_Chagni	-0.517	0.002	23	7	1.0
Axum_Adigrat	-0.09	-0.008***	62	3	7.4	Debre_Mark._Bahir_D.	-3.581***	0.031***	95	15	.
Axum_Maichwe	-0.279	-0.002	133	43	2.1	Debre_Mark._Chagni	2.071**	-0.028***	91	9	-0.6
Axum_Mekelle	-1.810***	0.016***	121	13	.	Bahir_Dar_Chagni	-1.353***	0.012***	10	3	.
Adigrat_Maichwe	-0.397	0.002	22	29	1.4	Kobo_Woldia	2.394***	-0.032***	52	16	-0.6
Adigrat_Mekelle	-0.282	-0.001	71	5	2.1	Kobo_Dessie	0.569	-0.011**	83	2	-1.5
Maichwe_Mekelle	-0.446	0.003	174	48	1.2	Kobo_Debre_Bir.	0.507	-0.011**	93	25	-1.7
Wolkite_Hosaena	-1.095**	0.002	23	11	.	Kobo_Batti	-0.508	0.002	253	44	1.0
Wolkite_Alaba	-1.716***	0.014*	119	19	.	Woldia_Dessie	0.264	-0.009**	28	4	-3.0
Wolkite_Awassa	-0.624**	0	13	4	0.7	Woldia_Debre_Bir.	-0.011	-0.005*	46	7	62.6
Wolkite_Hagere_selam	-0.924**	0.011	42	12	0.3	Woldia_Batti	-1.176***	0.008**	98	39	.
Wolkite_Wolayita_S.	-0.652	-0.001	68	6	0.7	Dessie_Debre_Bir.	1.123**	-0.021***	58	8	-0.9
Hosaena_Alaba	-1.555***	0.012***	197	39	.	Dessie_Batti	0.064	-0.005	168	27	-11.1
Hosaena_Awassa	-0.790***	0.008***	22	6	0.4	Debre_Birhan_Batti	-1.091**	0.007	95	27	.
Hosaena_Hagere_S.	-1.298***	0.010***	48	15	.	Gimbi_Nekemt	-1.635***	0.015***	135	37	.
Hosaena_Wolayita_S.	-1.959***	0.018***	55	16	.	Gimbi_Bedele	-0.784**	0.001	48	15	0.5
Alaba_Awassa	-2.024***	0.019***	210	22	.	Gimbi_Metu	0.116	-0.006	77	8	-6.3
Alaba_Hagere_selam	-1.448***	0.010***	140	34	.	Gimbi_Jimma	0.203	-0.011**	61	3	-3.8

Alaba_Wolayita_Sodo	-1.777***	0.015***	286	28	.	Gimbi_Agaro	-1.314***	0.011***	89	12	.
Hagere_S._Wolayita_S.	-1.646***	0.015***	46	16	.	Nekemt_Bedele	-1.393***	0.010**	46	4	.
Hagere_selam_Jinka	-1.697***	0.015***	24	2	.	Nekemt_Metu	-0.558**	0.003	21	6	0.8
Wolayita_Sodo_Jinka	-0.344	-0.006	13	1	1.6	Nekemt_Jimma	2.860***	-0.035***	157	31	-0.5
Wolayita_Sodo_Bonga	-3.245***	0.030***	101	7	.	Nekemt_Agaro	-1.373***	0.010**	59	5	.
Wolayita_Sodo_Amaya	-1.906***	0.017***	114	12	.	Bedele_Metu	-0.271	-0.010***	26	14	2.2
Alaba_Bonga	-1.334***	0.005	31	28	.	Bedele_Jimma	0.493	-0.015***	60	4	-1.7
Alaba_Amaya	-1.499***	0.012***	294	38	.	Bedele_Agaro	-1.995***	0.015***	46	11	.
Jinka_Amaya	-2.475***	0.022***	112	15	.	Metu_Jimma	1.479***	-0.024***	123	18	-0.8
Bonga_Amaya	-1.418***	0.006	82	20	.	Metu_Agaro	-1.011***	0.007**	92	6	.
Jigjiga_Hartishek	-0.882***	0.003	74	22	0.3	Jimma_Agaro	-0.242	-0.005	12	8	2.5
Jigjiga_Dollo	-0.470**	0.003	91	31	1.1	Nazareth_Shash.	-0.615	0.004	86	19	0.7
Hartishek_Dollo	-0.465	-0.002	131	18	1.1	Nazareth_Assela	-0.139	-0.001	12	17	4.6
Mambuk_Assosa	-0.864**	0.004	55	13	0.3	Nazareth_Assebe_T.	-1.290***	0.010**	229	31	.
Mambuk_Bambasi	-0.999***	0.008**	47	5	0.1	Shashemene_Assela	-2.735***	0.024***	167	34	.
Mambuk_Kemashi	-6.510***	0.086***	113	26	.	Shash._Assebe_T.	-1.062***	0.006	260	21	.
Assosa_Bambasi	-0.843*	0	11	11	0.4	Assela_Assebe_T.	-1.232***	0.011***	252	30	.
Assosa_Kemashi	-0.744*	-0.005	13	4	0.5	Shash._Negele	-0.332	-0.006*	80	18	1.7
Bambasi_Kemashi	0.236	-0.019***	16	10	-3	Negele_Moyalle	-1.021***	0.002	23	13	.

Note: Estimates with ***, **, and * are significant at 1, 5, and 10 percent levels of significance.

a. Beginning and end of period thresholds are expressed as percentages of average price during the respective periods in the markets paired.

Source: Results of analysis conducted using CSA data.

Appendix 5: Estimated results of TAR model with time varying thresholds, nominal price differences, intraregional oxen markets.

Market Pair	ρ	ρ*t	Beg. thr. (%)a	End thr. (%)a	Half Life	Market Pair	ρ	ρ*t	Beg. thr. (%)a	End thr. (%)a	Half Life
Endaselassie_Axum	-0.666**	0.004	13	22	0.6	Aysaita_Melka_werer	-1.466***	0.012***	20	15	.
Endaselassie_Adigrat	0.334	-0.011**	76	20	-2.4	Gondar_Debre_Mark.	-0.721	0.001	9	2	0.5
Endaselassie_Maichwe	-0.152	-0.001	130	62	4.2	Gondar_Bahir_Dar	-0.887***	0.004	21	6	0.3
Endaselassie_Mekelle	-0.788***	0.006**	9	12	0.4	Gondar_Chagni	-3.107***	0.027***	85	23	.
Axum_Adigrat	-0.879**	0.004	36	15	0.3	Debre_Mark._Bahir_D	-2.012***	0.016***	125	29	.
Axum_Maichwe	-1.109***	0.008*	32	23	.	Debre_Mark._Chagni	-0.654	0.002	18	9	0.7
Axum_Mekelle	-3.074***	0.028***	83	10	.	Bahir_Dar_Chagni	-1.767***	0.016***	93	13	.
Adigrat_Maichwe	-0.732**	0.007*	12	11	0.5	Kobo_Woldia	-0.969	0.002	69	12	0.2
Adigrat_Mekelle	-1.141***	0.009***	27	3	.	Kobo_Dessie	-1.983***	0.016***	58	13	.
Maichwe_Mekelle	-0.825***	0.008***	18	3	0.4	Kobo_Debre_Bir.	-0.219	-0.003	137	28	2.8
Wolkite_Hosaena	-1.786**	0.015	31	3	.	Kobo_Batti	0.676***	-0.013***	120	13	-1.3
Wolkite_Alaba	-0.186	0.001	62	7	3.4	Woldia_Dessie	-1.790***	0.015***	55	22	.
Wolkite_Awassa	-1.785***	0.027***	50	15	.	Woldia_Debre_Bir.	-0.582	0.001	100	27	0.8
Wolkite_Hagere_selam	-0.406	0.006	68	26	1.3	Woldia_Batti	1.081**	-0.021***	114	35	-0.9
Wolkite_Wolayita_S.	-0.163	-0.002	71	18	3.9	Dessie_Debre_Bir.	0.678*	-0.013***	103	11	-1.3
Hosaena_Alaba	-0.543	-0.002	102	21	0.9	Dessie_Batti	0.361	-0.008**	48	27	-2.2
Hosaena_Awassa	-1.597***	0.013***	11	14	.	Debre_Birhan_Batti	-1.074***	0.004	15	12	.
Hosaena_Hagere_S.	-0.545	0	90	20	0.9	Gimbi_Nekemt	-0.542	0.003	86	27	0.9
Hosaena_Wolayita_S.	-0.504	-0.001	25	5	1.0	Gimbi_Bedele	-0.651**	0.004	27	4	0.7
Alaba_Awassa	-0.804***	0.007***	102	18	0.4	Gimbi_Metu	-0.936***	0.006**	19	3	0.3
Alaba_Hagere_selam	-0.354	0.001	24	11	1.6	Gimbi_Jimma	-1.261***	0.011**	12	2	.
Alaba_Wolayita_Sodo	-0.680**	0.005	22	18	0.6	Gimbi_Agaro	-0.095	-0.007	34	2	6.9
Hagere_S._Wolayita_S.	-0.963**	0.008	160	32	0.2	Nekemt_Bedele	-0.854***	0.007**	48	41	0.4
Hagere_selam_Jinka	-0.565*	0.001	136	26	0.8	Nekemt_Metu	-1.127***	0.010***	147	36	.
Wolayita_Sodo_Jinka	-0.390*	-0.002	63	18	1.4	Nekemt_Jimma	-2.573***	0.018**	46	9	.

Wolayita_Sodo_Bonga	0.098	-0.003	191	17	-7.4	Nekemt_Agaro	-1.108***	0.008**	101	24	.
Wolayita_Sodo_Amaya	-0.347	0.002	25	48	1.6	Bedele_Metu	0.058	-0.010***	32	13	-12.3
Alaba_Bonga	-0.02	-0.003	14	3	34.7	Bedele_Jimma	-1.225***	0.011***	158	21	.
Alaba_Amaya	0.638	-0.012**	246	19	-1.4	Bedele_Agaro	-0.425	0.002	43	22	1.3
Jinka_Amaya	-0.908***	0.007**	186	43	0.3	Metu_Jimma	-1.498***	0.013**	167	40	.
Bonga_Amaya	-1.801***	0.015***	57	12	.	Metu_Agaro	1.242	-0.018**	56	19	-0.9
Jigjiga_Hartishek	-0.393**	0.001	53	8	1.4	Jimma_Agaro	-1.717***	0.015***	58	8	.
Jigjiga_Dollo	-0.502	0.004	188	33	1.0	Nazareth_Shash.	-0.215	-0.001	11	11	2.9
Hartishek_Dollo	-0.886***	0.011***	167	34	0.3	Nazareth_Assela	-1.035**	0.009*	40	5	.
Mambuk_Assosa	-0.600*	-0.001	48	9	0.8	Nazareth_Assebe_T.	-0.717*	0.005	29	5	0.5
Mambuk_Bambasi	-0.872***	0.005	39	19	0.3	Shashemene_Assela	-1.119**	0.005	39	5	.
Mambuk_Kemashi	-0.43	0.002	51	11	1.2	Shash._Assebe_T.	-0.979***	0.007**	90	9	0.2
Assosa_Bambasi	-1.278***	0.004	22	2	.	Assela_Assebe_T.	-0.880***	0.007**	39	16	0.3
Assosa_Kemashi	-0.950**	0.005	18	12	0.2	Shash._Negele	-0.800***	0.006**	30	22	0.4
Bambasi_Kemashi	-0.947**	0.006	76	10	0.2	Negele_Moyalle	-1.357***	0.010***	65	26	.

Note: Estimates with ***, **, and * are significant at 1, 5, and 10 percent levels of significance.

a. Beginning and end of period thresholds are expressed as percentages of average price during the respective periods in the markets paired.

Source: Results of analysis conducted using CSA data.

Appendix 6: Estimated results of TAR model with time varying thresholds, nominal price differences, and interregional bulls markets.

Regions	Market pair	ρ	ρ*t	Beg. thr. (%)[a]	End thr. (%)[a]	Half Life
Tigray and Afar	Adigrat_Aysaita	-0.228	-0.002	13	14	2.7
	Adigrat_Melka_werer	-0.18	-0.004*	29	4	3.5
	Maichwe_Aysaita	-2.111***	0.019***	115	12	.
	Maichwe_Melka_werer	-0.805***	0.006***	49	5	0.4
	Mekelle_Aysaita	0.699	-0.012**	112	6	-1.3
	Mekelle_Melka_werer	-0.148	-0.001	46	10	4.3
Amhara and Afar	Aysaita_Kobo	-2.088***	0.018***	53	7	.
	Aysaita_Woldia	-1.359***	0.011*	61	17	.
	Aysaita_Dessie	0.864*	-0.018***	75	3	-1.1
	Aysaita_Debre_Birhan	-0.081	-0.006**	46	8	8.2
	Aysaita_Batti	-0.673*	0.003	75	38	0.6
	Melka_werer_Kobo	-1.382***	0.009**	96	4	.
	Melka_werer_Woldia	-0.264	-0.006**	38	13	2.3
	Melka_werer_Dessie	-0.196	-0.007	83	12	3.2
	Melka_w._Debre_Bir.	-0.173	-0.006**	34	10	3.7
	Melka_werer_Batti	-0.942**	0.006	139	34	0.2
Amhara and Benish.-Gumuz	Bahir_Dar_Mambuk	-0.898	0.006	147	31	0.3
	Bahir_Dar_Kemashi	-0.909*	0.01	8	2	0.3
	Chagni_Mambuk	-1.023***	0.008**	18	12	.
	Chagni_Kemashi	-1.187	0.011	44	22	.
Oromia and SNNP	Metu_Alaba	-0.965***	0.001	154	7	0.2
	Metu_Bonga	-3.101***	0.028***	76	19	.
	Metu_Amaya	-0.169	0	94	19	3.8
	Agaro_Alaba	-1.636***	0.013***	234	30	.
	Agaro_Bonga	-2.852***	0.025***	103	21	.
	Agaro_Amaya	-1.242***	0.011***	68	4	.
	Bedele_Alaba	-0.892***	0	19	14	0.3

Regions	Market pair	ρ	ρ*t	Beg. thr. (%)[a]	End thr. (%)[a]	Half Life
Amhara and Oromia	Bahir_Dar_Gimbi	-3.332***	0.031***	141	16	.
	Bahir_Dar_Nekemt	-1.387***	0.011**	58	10	.
	Chagni_Gimbi	-0.661**	0.006	10	6	0.6
	Chagni_Nekemt	-2.999***	0.027***	99	32	.
	Debre_Birhan_Assebe_T.	-1.032***	0.007*	84	18	.
Oromia, Harar, Dire Dawa, and Somali	Negele_Dollo	-0.614*	0.003	25	26	0.7
	Dollo_Moyalle	-0.824***	-0.002	55	5	0.4
	Assebe_T._Jigjiga	-0.986***	0.006**	67	5	0.2
	Assebe_T._Hartishek	-0.850**	0.005	95	18	0.4
	Assebe_Teferi_Harar	-0.623	0.002	36	5	0.7
	Assebe_T._Dire Dawa	-1.559**	0.009	51	16	.
	Jigjiga_Harar	-0.451*	-0.004	38	13	1.2
	Jigjiga_DD_Sabian	-0.278	-0.006	14	7	2.1
	Hartishek_Harar	-1.334***	0.015*	20	5	.
	Hartishek_Dire Dawa	-0.005	-0.011	71	5	153
	Harar_Dire Dawa	-1.027***	-0.003	9	3	.
	Hartishek_Harar	-1.334***	0.015*	20	5	.
Oromia and Benishangul Gumuz	Nekemt_Assosa	-1.072*	0.003	83	15	.
	Nekemt_Bambasi	-1.174***	0.008**	54	15	.
	Nekemt_Kemashi	1.958**	-0.041***	59	18	-0.6
	Bedele_Assosa	1.054	-0.019*	145	23	-1.0
	Bedele_Bambasi	-0.698*	0.002	41	21	0.6
	Bedele_Kemashi	3.808***	-0.049***	99	18	-0.4
	Metu_Assosa	-1.065	0.003	88	16	.
	Metu_Bambasi	-0.876**	0.003	13	7	0.3
	Metu_Kemashi	1.495	-0.026**	77	16	-0.8
	Gimbi_Assosa	-0.11	-0.002	14	37	6.0

Bedele_Bonga	-1.126***	0.001	19	15	.		Gimbi_Bambasi	-0.926***	0.009**	88	36	0.3
Bedele_Amaya	-0.354	-0.001	42	18	1.6		Gimbi_Kemashi	1.376***	-0.022***	43	31	-0.8
Nazareth_Hosaena	-0.721**	0.007	21	22	0.5		Nekemt_Gambella	-1.242***	0.008*	54	19	.
Nazareth_Alaba	-1.548***	0.012***	148	14	.	**Oromia and Gambella**	Bedele_Gambella	-0.636	-0.004	126	23	0.7
Nazareth_Awassa	-1.335***	0.013***	44	3	.		Metu_Gambella	-0.858*	0	53	13	0.4
Shashemene_Hosaena	-2.093***	0.018***	218	49	.		Agaro_Gambella	-1.194***	0.008*	159	21	.
Shashemene_Alaba	-1.451***	0.008**	216	25	.		Gimbi_Gambella	-0.599	0.003	47	5	0.8
Shashemene_Awassa	-1.013**	0.009**	62	3	.							

Note: Estimates with ***, **, and * are significant at 1, 5, and 10 percent levels of significance.
a. Beginning and end of period thresholds are expressed as percentages of average price during the respective periods in the markets paired.
Source: Results of analysis conducted using CSA data.

Appendix 7: Estimated results of TAR model with time varying thresholds, nominal price differences, interregional oxen markets.

Regions	Market pair	P	ρ*t	Beg. thr. (%)a	End thr. (%)a	Half Life	Regions	Market pair	ρ	ρ*t	Beg. thr.(%)a	End thr. (%)a	Half Life
	Adigrat_Aysaita	-0.418	0.001	100	14	1.3		Bahir_Dar_Gimbi	-0.794**	0.004	109	27	0.4
	Adigrat_Melka_werer	-0.665**	-0.001	102	3	0.6	Amhara and	Bahir_Dar_Nekemt	-0.242	-0.006	77	16	2.5
Tigray	Maichwe_Aysaita	-2.660***	0.025***	193	47	.	Oromia	Chagni_Gimbi	-0.717	0.003	69	31	0.5
and Afar	Maichwe_Melka_werer	-2.135***	0.020***	100	5	.		Chagni_Nekemt	-2.732***	0.024***	48	8	.
	Mekelle_Aysaita	-0.651*	0.002	16	11	0.7		Debre_Birhan_Assebe_T.	-0.371	-0.006	22	9	1.5
	Mekelle_Melka_werer	-2.973***	0.027***	105	5	.		Negele_Dollo	-1.203***	0.012***	101	3	.
	Aysaita_Kobo	-1.947***	0.016***	150	22	.		Dollo_Moyalle	-0.692**	0.003	25	3	0.6
	Aysaita_Woldia	-2.236***	0.020***	102	27	.		Assebe_T._Jigjiga	0.115	-0.009***	38	9	-6.4
	Aysaita_Dessie	-0.288	-0.001	50	8	2.0		Assebe_T._Hartishek	-1.187***	0.010***	154	6	.
	Aysaita_Debre_Birhan	1.936***	-0.030***	145	9	-0.6	Oromia,	Assebe_Teferi_Harar	-1.108***	0.008	14	7	.
Amhara	Aysaita_Batti	0.405	-0.008**	114	30	-2.0	Harar, Dire	Assebe_T._Dire Dawa	-0.246	-0.005	73	14	2.5
and Afar	Melka_werer_Kobo	-0.061	-0.012***	38	8	10.9	Dawa, and	Jigjiga_Harar	0.076	-0.017**	104	6	-9.5
	Melka_werer_Woldia	-0.237	-0.004	52	18	2.6	Somali	Jigjiga_DD_Sabian	0.367	-0.012***	58	6	-2.2
	Melka_werer_Dessie	-2.262***	0.019***	86	5	.		Hartishek_Harar	-1.920***	0.018**	27	18	.
	Melka_w._Debre_Bir.	-0.141	-0.004	30	22	4.6		Hartishek_Dire Dawa	-0.487	-0.001	19	22	1.0
	Melka_werer_Batti	0.630*	-0.014***	126	14	-1.4		Harar_Dire Dawa	-1.378**	0.004	60	1	.
Amhara	Bahir_Dar_Mambuk	-1.328***	0.009***	12	8	.		Hartishek_Harar	-1.920***	0.018**	27	18	.
and	Bahir_Dar_Kemashi	-0.984***	0.007**	99	36	0.2		Nekemt_Assosa	-1.158**	0.008	96	20	.
Benish.-	Chagni_Mambuk	-1.459***	0.011***	26	4	.	Oromia and	Nekemt_Bambasi	-1.175***	0.009***	51	19	.
Gumuz	Chagni_Kemashi	0.544	-0.010*	68	33	-1.6	Benishangul	Nekemt_Kemashi	-0.827**	0.006*	134	34	0.4
Oromia	Metu_Alaba	0.428	-0.009*	115	10	-1.9	Gumuz	Bedele_Assosa	0.611	-0.009	112	17	-1.5
and	Metu_Bonga	-0.530*	0	41	12	0.9		Bedele_Bambasi	-1.162***	0.011***	15	18	.

SNNP	Metu_Amaya	-0.594	0	103	29	0.8
	Agaro_Alaba	0.799*	-0.014**	101	28	-1.2
	Agaro_Bonga	-0.202	-0.003	51	6	3.1
	Agaro_Amaya	-1.182***	0.010***	108	13	.
	Bedele_Alaba	0.693*	-0.011**	170	3	-1.3
	Bedele_Bonga	-1.296***	0.009***	12	7	.
	Bedele_Amaya	-0.421	-0.004	22	19	1.3
	Nazareth_Hosaena	-0.733	0.003	40	3	0.5
	Nazareth_Alaba	-0.384	0.002	83	15	1.4
	Nazareth_Awassa	-0.644**	0.005*	26	7	0.7
	Shashemene_Hosaena	-0.495	-0.001	7	14	1.0
	Shashemene_Alaba	-0.304	0.001	30	6	1.9
	Shashemene_Awassa	-1.017***	0.009***	24	16	.
	Bedele_Kemashi	-0.175	-0.004	12	13	3.6
	Metu_Assosa	-0.345	0	16	10	1.6
	Metu_Bambasi	-1.169***	0.010**	36	3	.
	Metu_Kemashi	0.415	-0.012***	57	9	-2.0
	Gimbi_Assosa	-0.319	-0.003	25	17	1.8
	Gimbi_Bambasi	-1.020***	0.006*	11	11	.
	Gimbi_Kemashi	-0.723**	0.003	48	4	0.5
Oromia and Gambella	Nekemt_Gambella	0.438	-0.010**	69	5	-1.9
	Bedele_Gambella	-0.292	0.002	66	31	2.0
	Metu_Gambella	-0.217	-0.001	63	26	2.8
	Agaro_Gambella	-0.069	-0.003	13	11	9.6
	Gimbi_Gambella	0.595	-0.012**	56	16	-1.5

Note: Estimates with ***, **, and * are significant at 1, 5, and 10 percent levels of significance.

a. Beginning and end of period thresholds are expressed as percentages of average price during the respective periods in the markets paired.

Source: Results of analysis conducted using CSA data.

Appendix 8. Estimated results of TAR model with time varying thresholds, nominal price differences, large population bulls markets.

City	With/market pair	P	ρ*t	Beg. thr.(%)a	End thr. (%)a	Half Life	City	With/market pair	ρ	ρ*t	Beg. thr.(%)a	End thr. (%)a	Half Life
Dire Dawa	Adigrat	-0.68	0.00	32	2	0.6	Bahir Dar	Metu	-1.433***	0.012***	25	10	.
	Mekelle	-0.35	0.00	117	14	1.6		Jimma	-1.853**	0.02	88	16	.
	Aysaita	-0.57	0.00	24	15	0.8		Shashemene	-2.486***	0.020***	154	24	.
	Melka_werer	-0.66	0.00	21	4	0.6		Jigjiga	-0.865***	0.006*	69	22	0.3
	Gondar	-5.072***	0.047***	71	12	.		Awassa	-1.531***	0.013**	167	21	.
	Dessie	-0.42	-0.01	65	5	1.3		Gambella	-3.455***	0.031***	128	3	.
	Debre_Birhan	-0.87	0.00	43	8	0.3		Harar	-1.748***	0.025***	22	19	.
	Debre_Markos	-3.840**	0.030*	119	13	.		Gondar	-1.004**	0.01	45	20	.
	Bahir_Dar	-2.916***	0.023**	67	4	.		Dessie	0.81	-0.014**	106	7	-1.2
	Chagni	-2.985***	0.025**	105	5	.		Debre_Birhan	-0.63	0.00	19	3	0.7
	Metu	-2.476***	0.020**	25	2	.		Debre_Markos	-0.52	0.00	105	12	0.9
	Jimma	2.109**	-0.031***	175	23	-0.6	Mekelle	Chagni	-0.866**	0.01	26	27	0.3
	Nazareth	-0.80	0.00	22	9	0.4		Metu	-1.541***	0.013***	115	26	.
	Shashemene	-0.03	-0.01	98	9	23.0		Jimma	1.687***	-0.022***	139	34	-0.7
	Awassa	-3.602***	0.033***	122	13	.		Shashemene	-0.24	0.00	112	23	2.6
	Gambella	-3.123**	0.02	128	19	.		Jigjiga	-0.661**	0.00	7	2	0.6
Nazareth	Adigrat	-0.26	0.00	11	10	2.3		Awassa	-0.718**	0.01	50	3	0.5
	Mekelle	-1.869***	0.016***	126	5	.		Gambella	-0.74	0.00	38	33	0.5
	Aysaita	-0.897***	0.009**	51	18	0.3		Harar	-0.861***	0.011*	53	12	0.4
	Melka_werer	1.114*	-0.014**	133	27	-0.9	Awassa	Adigrat	-1.548***	0.015***	80	14	.
	Gondar	-0.22	0.00	11	23	2.8		Aysaita	-0.916***	0.008***	14	21	0.3
	Dessie	1.370***	-0.018***	147	30	-0.8		Gondar	-1.844***	0.017***	118	18	.

	Debre_Birhan	-0.22	0.00	31	21	2.8	Dessie	-0.734**	0.007**	17	8	0.5
	Debre_Markos	1.881***	-0.024***	136	32	-0.7	Debre_Birhan	-0.707***	0.007***	57	13	0.6
	Bahir_Dar	-1.225***	0.011**	78	7	.	Debre_Markos	-1.142**	0.010*	207	20	.
	Chagni	-0.44	0.00	23	26	1.2	Chagni	-0.618**	0.006**	26	7	0.7
	Metu	-0.11	0.00	30	13	6.1	Metu	-1.732***	0.016***	135	17	.
	Jimma	2.632***	-0.032***	175	38	-0.5	Jimma	-0.848**	0.008**	285	35	0.4
	Jigjiga	-0.562**	0.00	17	10	0.8	Jigjiga	-0.820***	0.007***	71	9	0.4
	Gambella	-0.43	0.00	64	31	1.2	Gambella	-1.366***	0.013***	44	2	.
	Harar	-2.982***	0.041***	123	16	.	Harar	-0.547**	0.00	43	2	0.9
	Adigrat	-1.187*	0.01	80	14	.	Debre_Markos_Metu	0.27	-0.010**	54	4	-2.9
	Mekelle	0.03	-0.01	29	15	-22.2	Debre_Markos_Jimma	0.34	-0.013*	23	22	-2.4
Bahir Dar	Aysaita	-4.779***	0.043***	72	13	.	Debre_M.._Shashemene	0.36	-0.014*	102	13	-2.3
	Melka_werer	-4.576***	0.042***	107	7	.	Chagni_Metu	-0.46	0.00	13	11	1.1
	Dessie	-0.12	0.00	17	12	5.6	Chagni_Jimma	2.946***	-0.035***	88	17	-0.5
	Debre_Birhan	-0.563**	0.00	26	19	0.8	Chagni_Shashemene	-0.42	0.00	63	31	1.3

Note: Estimates with ***, **, and * are significant at 1, 5, and 10 percent levels of significance.
a. Beginning and end of period thresholds are expressed as percentages of average price during the respective periods in the markets paired.
Source: Results of analysis conducted using CSA data.

Appendix 8: Estimated results of TAR model with varying thresholds, nominal price differences...bulls markets...contd.

City	With/market pair	ρ	ρ*t	Beg. thr.(%)a	End thr. (%)a	Half Life
	Adigrat	-0.529**	0.00	84	13	0.9
	Aysaita	-1.848***	0.027***	72	20	.
	Melka_werer	-1.548***	0.022***	72	12	.
	Gondarr	-0.36	-0.012*	6	1	1.6
	Dessie	-1.457***	0.023***	44	14	.
Harar	Debre_Birhan	-0.943***	0.010*	78	5	0.2
	Debre_Markos	-1.111***	0.016**	27	14	.
	Chagni	-0.923**	0.011*	18	9	0.3
	Metu	-2.059***	0.029***	33	7	.
	Jimma	-2.589***	0.037***	160	23	.
	Shashemene	-0.01	-0.01	200	23	54.4
	Gambella	-0.627***	-0.010***	33.96	5.45	0.7
	Adigrat	-0.29	0.00	48.00	5.26	2.0
	Aysaita	-0.06	-0.007*	31.33	18.29	11.0
	Melka_werer	-0.705**	0.00	45.33	6.06	0.6
	Dessie	-0.26	0.00	17.30	1.95	2.3
	Debre_Birhan	-0.547**	0.00	13.91	4.57	0.9
Gondar	Metu	-0.787**	0.00	10.00	8.00	0.4
	Jimma	1.08	-0.018**	97.50	16.97	-0.9
	Shashemene	0.23	-0.012**	123.08	26.67	-3.4
	Jigjiga	-0.788***	0.005*	28.57	10.81	0.4
	Gambella	-0.70	0.00	35.90	7.14	0.6
Jigjiga	Adigrat	-0.402*	0.00	14.86	5.31	1.4
	Aysaita	-0.494**	0.00	70.68	16.52	1.0

City	With/market pair	ρ	ρ*t	Beg. thr.(%)a	End thr. (%)a	Half Life
	Jimma	-0.69	0.00	14	12	0.6
Aysaita	Shashemene	0.41	-0.014**	97	3	-2.0
	Gambella	-0.47	0.00	20	26	1.1
	Adigrat	-1.831*	0.01	88	15	.
	Melka_werer	-0.677*	0.00	57	4	0.6
	Dessie	-0.35	0.00	27	14	1.6
Gambella	Debre_Birhan	-0.941***	0.00	49	20	0.2
	Debre_Markos	-0.74	0.00	42	38	0.5
	Chagni	-0.834*	0.01	11	4	0.4
	Jimma	0.29	-0.010*	100	19	-2.7
	Shashemene	-0.54	0.00	117	6	0.9
Adigrat_Dessie		-0.05	-0.007*	22	12	12.7
Adigrat_Debre_Birhan		-0.554**	0.00	37	15	0.9
Adigrat_Debre_Markos		0.05	-0.008**	42	5	-14.3
Adigrat_Chagni		-0.790*	0.01	57	22	0.4
Adigrat_Metu		-0.19	0.00	35	12	3.3
Adigrat_Jimma		0.942**	-0.016***	96	27	-1.0
Adigrat_Shashemene		-0.14	-0.006**	34	5	4.5
Melka_werer_Debre_Markos		-0.79	0.00	29	3	0.4
Melka_werer_Chagni		-0.662**	0.01	33	6	0.6
Melka_werer_Metu		-1.526***	0.010**	77	4	.
Melka_werer_Jimma		0.48	-0.015***	49	15	-1.8
Melka_werer_Shashemene		-0.34	0.00	60	4	1.7
Dessie_Debre_Markos		-0.35	0.00	22	19	1.6

	Melka_werer	-0.479**	0.00	80.00	8.18	1.1	Dessie_Chagni	-0.32	0.00	9	10	1.8
	Dessie	0.51	-0.012***	77.19	10.77	-1.7	Dessie_Metu	-0.34	0.00	24	14	1.7
	Debre_Birhan	-0.956***	0.00	18.18	19.57	0.2	Dessie_Jimma	2.320***	-0.032***	109	19	-0.6
	Debre_Markos	-0.18	0.00	26.87	30.99	3.5	Dessie_Shashemene	0.85	-0.018***	104	9	-1.1
	Chagni	-1.012***	0.009**	90.32	38.89	.	Debre_Birhan_Debre_Mark os	0.42	-0.012**	83	9	-2.0
	Metu	-0.611***	0.00	61.54	5.37	0.7	Debre_Birhan_Chagni	-0.38	0.00	31	32	1.4
	Jimma	0.751**	-0.015***	116.92	27.27	-1.2	Debre_Birhan_Metu	-0.422*	0.00	46	17	1.3
	Shashemene	-0.910***	0.00	113.04	31.71	0.3	Debre_Birhan_Jimma	1.840***	-0.026***	95	24	-0.7
	Gambella	-1.113***	0.008**	89.06	13.33	.	Debre_Birhan_Shashemene	0.17	-0.013***	27	6	-4.4
	Debre_Markos	-1.137**	0.00	7.79	14.33	.	Metu_Shashemene	-0.743*	0.00	152.73	22.94	0.51
Aysaita	Chagni	-0.600**	0.00	10.20	35.29	0.8	Jimma_Shashemene	1.521**	-0.024***	127.27	25.41	-0.75
	Metu	-1.633***	0.012**	82.19	18.97	.						

Note: Estimates with ***, **, and * are significant at 1, 5, and 10 percent levels of significance.
a. Beginning and end of period thresholds are expressed as percentages of average price during the respective periods in the markets paired.
Source: Results of analysis conducted using CSA data.

Appendix 9: Estimated results of TAR model with varying thresholds, nominal price differences, large population oxen markets.

City	With market pair	ρ	ρ*t	Beg. thr.(%)a	End thr. (%)a	Half Life
Dire Dawa	Adigrat	-0.13	0.00	61	33	4.9
	Mekelle	0.43	-0.012**	104	5	-1.9
	Aysaita	0.41	-0.011**	52	9	-2.0
	Melka_werer	-0.15	0.00	69	28	4.3
	Gondar	-0.06	-0.01	82	10	10.9
	Dessie	0.62	-0.012**	127	4	-1.4
	Debre_Birhan	-0.03	-0.01	19	14	22.1
	Debre_Markos	-0.41	0.00	42	44	1.3
	Bahir_Dar	0.16	-0.01	103	4	-4.8
	Chagni	-0.44	0.00	51	31	1.2
	Metu	-0.34	0.00	31	38	1.7
	Jimma	0.51	-0.014**	126	9	-1.7
	Nazareth	-0.12	0.00	32	6	5.3
	Shashemene	-0.05	0.00	61	18	12.7
	Awassa	-0.12	-0.01	15	5	5.4
	Gambella	-0.11	-0.01	18	5	6.2
Nazareth	Adigrat	-0.33	0.00	13	2	1.7
	Mekelle	-0.590*	0.00	7	5	0.8
	Aysaita	0.39	-0.01	114	16	-2.1
	Melka_werer	-0.66	0.01	79	7	0.6
	Gondar	-0.25	0.00	33	3	2.5
	Dessie	0.62	-0.01	50	13	-1.4
	Debre_Birhan	-0.17	0.00	15	15	3.6
	Debre_Markos	-0.39	0.00	34	13	1.4
Bahir Dar	Metu	-0.942***	0.008**	114	26	0.2
	Jimma	-0.25	-0.01	27	11	2.4
	Shashemene	-0.942***	0.007**	103	11	0.2
	Jigjiga	0.388**	-0.014***	59	23	-2.1
	Awassa	-1.315***	0.010***	11	11	.
	Gambella	-0.10	0.00	22	7	6.4
	Harar	-0.43	-0.01	35	13	1.3
Mekelle	Gondar	-1.285***	0.010***	91	7	.
	Dessie	-0.654**	0.00	11	13	0.7
	Debre_Birhan	0.47	-0.013***	94	19	-1.8
	Debre_Markos	-2.070***	0.017***	30	17	.
	Chagni	-2.800***	0.025***	62	15	.
	Metu	-1.815***	0.017***	47	17	.
	Jimma	-0.703*	0.00	10	15	0.6
	Shashemene	-1.687***	0.015***	55	2	.
	Jigjiga	0.13	-0.006**	132	10	-5.9
	Awassa	-0.945***	0.006*	61	3	0.2
	Gambella	-2.779**	0.024**	83	16	.
	Harar	-1.370***	0.018**	118	18	.
Awassa	Adigrat	-0.890***	0.007**	59	10	0.3
	Aysaita	-0.398*	0.00	43	4	1.4
	Gondar	-1.121***	0.010***	31	2	.
	Dessie	-0.781***	0.006**	9	5	0.5
	Debre_Birhan	-0.37	0.00	84	10	1.5

	Bahir_Dar	-1.052**	0.01	28	2	.	Debre_Markos	-1.083***	0.008***	14	18	.
	Chagni	-0.750**	0.006*	38	3	0.5	Chagni	-1.106***	0.010***	16	11	.
	Metu	-0.25	0.00	69	25	2.4	Metu	-0.613***	0.006***	16	6	0.7
	Jimma	-1.280**	0.010*	41	18	.	Jimma	-1.121***	0.007**	11	9	.
	Jigjiga	0.16	-0.006**	27	22	-4.6	Jigjiga	-0.08	-0.004*	109	19	8.0
	Gambella	2.778***	-0.034***	86	16	-0.5	Gambella	-0.615*	0.01	26	8	0.7
	Harar	-0.710*	0.00	43	2	0.6	Harar	-1.094**	0.01	21	14	.
Bahir Dar	Adigrat	-0.619*	0.00	100	25	0.7	Debre_Markos_Metu	0.27	0.20	-0.011**	62	-3.8
	Mekelle	-0.646**	0.00	59	12	0.7	Debre_Markos_Jimma	0.34	-2.056***	0.018***	148	.
	Aysaita	0.14	-0.01	114	10	-5.4	Debre_Mar._Shashemene	0.36	-1.244***	0.01	18	.
	Melka_werer	-1.538***	0.013***	79	5	.	Chagni_Metu	-0.46	1.125**	-0.015**	51	-0.9
	Dessie	-0.595*	0.00	5	3	0.8	Chagni_Jimma	2.946***	-3.413***	0.031***	97	.
	Debre_Birhan	-0.14	-0.008*	20	10	4.5	Chagni_Shashemene	-0.42	-1.862***	0.015**	91	.

Note: Estimates with ***, **, and * are significant at 1, 5, and 10 percent levels of significance.

a. Beginning and end of period thresholds are expressed as percentages of average price during the respective periods in the markets paired.

Source: Results of analysis conducted using CSA data.

Appendix 9: Estimated results of TAR model with time varying thresholds, nominal price differences, ..oxen markets…contd.

City	With/market pair	ρ	ρ*t	Beg. thr.(%)a	End thr. (%)a	Half Life
Harar	Adigrat	-1.112*	0.01	123	22	.
	Aysaita	-0.953**	0.012*	82	25	0.2
	Melka_werer	-1.231***	0.014*	164	27	.
	Gondarr	-0.53	0.00	14	11	0.9
	Dessie	-1.210**	0.01	120	23	.
	Debre_Birhan	-1.235**	0.01	18	17	.
	Debre_Markos	-0.34	0.00	39	27	1.7
	Chagni	-1.874***	0.023***	111	29	.
	Metu	-1.382***	0.015**	127	31	.
	Jimma	-0.58	0.00	68	21	0.8
	Shashemene	-1.522***	0.019***	115	25	.
	Gambella	-0.13	-0.03	20.36	6.82	5.1
Gondar	Adigrat	-0.696**	0.00	60.69	14.10	0.6
	Aysaita	-0.13	0.00	35.20	7.06	4.9
	Melka_werer	-0.33	0.00	20.80	9.04	1.7
	Dessie	0.08	-0.01	48.37	13.08	-8.6
	Debre_Birhan	-0.31	-0.01	25.26	11.59	1.9
	Metu	-0.43	0.00	112.50	28.75	1.2
	Jimma	-1.617***	0.012**	85.88	16.59	.
	Shashemene	-0.565*	0.00	11.25	2.61	0.8
	Jigjiga	-0.06	0.00	94.63	6.81	10.5
	Gambella	0.23	-0.010*	58.82	6.27	-3.3
Jigjiga	Adigrat	-0.11	0.00	160.00	16.67	5.8
	Aysaita	0.10	-0.008*	155.56	27.18	-7.6
	Melka_werer	0.07	-0.005**	101.11	29.67	-10.4
	Dessie	0.10	-0.005**	105.77	6.46	-7.6
	Debre_Birhan	0.484**	-0.017***	89.80	7.08	-1.8

City	With/market pair	ρ	ρ*t	Beg. thr.(%)a	End thr. (%)a	Half Life
Aysaita	Jimma	-0.40	0.00	92	5	1.4
	Shashemene	-2.679***	0.022***	89	15	.
	Gambella	-0.09	-0.006*	84	10	7.7
Gambella	Adigrat	-0.36	0.00	97	19	1.6
	Melka_werer	-0.05	-0.004*	41	21	14.7
	Dessie	0.52	-0.010**	58	2	-1.6
	Debre_Birhan	2.306***	-0.031***	52	8	-0.6
	Debre_Markos	-1.218*	0.01	85	13	.
	Chagni	-2.353**	0.020**	119	33	.
	Jimma	-0.09	0.00	26	12	7.2
	Shashemene	-0.52	0.00	67	8	1.0
Adigrat_Dessie		-0.766***	0.005*	30	3	0.5
Adigrat_Debre_Birhan		-0.737*	0.00	108	22	0.5
Adigrat_Debre_Markos		-0.38	0.00	16	10	1.4
Adigrat_Chagni		-0.969***	0.007*	75	2	0.2
Adigrat_Metu		-0.09	0.00	39	15	7.0
Adigrat_Jimma		-2.597***	0.023***	61	22	.
Adigrat_Shashemene		-0.35	0.00	37	5	1.6
Melka_werer_Debre_Markos		-1.559***	0.01	34	3	.
Melka_werer_Chagni		-2.215***	0.019***	77	13	.
Melka_werer_Metu		-1.341***	0.008*	59	4	.
Melka_werer_Jimma		-2.560***	0.024***	69	4	.
Melka_werer_Shashemene		-1.977***	0.015**	61	3	.
Dessie_Debre_Markos		-2.085***	0.016***	97	21	.
Dessie_Chagni		-1.205***	0.010***	10	32	.
Dessie_Metu		-0.794**	0.006*	31	15	0.4
Dessie_Jimma		-1.769**	0.014*	81	18	.

	Debre_Markos	-0.21	0.00	162.44	30.95	2.9	Dessie_Shashemene	-1.171***	0.008**	74	13	.
	Chagni	-0.443**	0.00	133.64	37.69	1.2	Debre_Birhan_Debre_Markos	-0.505*	0.00	24	27	1.0
	Metu	-0.370**	0.00	139.53	28.54	1.5	Debre_Birhan_Chagni	-0.849*	0.00	93	26	0.4
	Jimma	0.452***	-0.013***	48.89	5.66	-1.9	Debre_Birhan_Metu	-0.43	0.00	130	35	1.2
	Shashemene	-0.04	0.00	141.40	24.83	16.0	Debre_Birhan_Jimma	0.811**	-0.020***	81	17	-1.2
	Gambella	-0.49	-0.01	88.89	19.80	1.0	Debre_Birhan_Shashemene	0.04	-0.01	80	5	-19.1
	Debre_Markos	-2.408***	0.019***	136.75	21.33	.	Metu_Shashemene	-1.958***	0.014***	58.82	17.99	.
Aysaita	Chagni	-0.903***	0.007**	45.71	21.45	0.3	Jimma_Shashemene	-1.346***	0.011**	10.00	26.42	.
	Metu	-2.343***	0.021***	87.41	23.74	.						

Note: Estimates with ***, **, and * are significant at 1, 5, and 10 percent levels of significance.
a. Beginning and end of period thresholds are expressed as percentages of average price during the respective periods in the markets paired.
Source: Results of analysis conducted using CSA data.

Appendix 10: Estimated results of TAR model with time varying thresholds, nominal price differences, Addis Ababa Kotebe and other bulls markets.

Market	P	ρ*t	Beg. thr.(%)a	End thr. (%)a	Half Life	Market	ρ	ρ*t	Beg. thr.(%)a	End thr. (%)a	Half Life
Endaselassie	-0.778***	0.002	59	18	0.5	Assebe_Teferi	-0.329	-0.002	200	32	1.7
Axum	-0.234	-0.005	104	10	2.6	Negele	-0.285	-0.003	90	12	2.1
Adigrat	-0.048	-0.006*	62	30	14.1	Moyalle	-0.232	-0.002	94	33	2.6
Maichwe	-0.648***	0.003	91	19	0.7	Hartishek	0.047	-0.008***	95	9	-15.0
Mekelle	-0.105	-0.002	27	5	6.2	Dollo	-0.068	-0.006**	84	21	9.8
Aysaita	-0.155	-0.003	81	17	4.1	Jigjiga	-1.068**	0.002	96	8	.
Melka_werer	-0.06	-0.009***	88	11	11.2	Mambuk	-0.216	-0.001	122	34	2.8
Gondar	-0.078	-0.005**	45	17	8.5	Mender_7	-0.909*	0.006	227	67	0.3
Kobo	-0.095	-0.008***	65	8	7.0	Assosa	-0.153	-0.004	92	22	4.2
Woldia	0.08	-0.010***	61	20	-9.0	Bambasi	-0.168	-0.003	67	22	3.8
Dessie	0.084	-0.009***	80	28	-8.6	Kemashi	-0.015	-0.011**	101	26	46.1
Debre_Birhan	-0.013	-0.009***	27	6	54.8	Wolkite	-0.182	-0.001	108	30	3.5
Debre_Markos	-0.051	-0.010***	98	9	13.2	Hosaena	-0.576***	0.003	113	22	0.8
Bahir_Dar	-0.796***	0.005	91	28	0.4	Alaba	-0.618***	0.001	150	26	0.7
Chagni	-0.383**	0.001	56	8	1.4	Awassa	-0.342**	0.003**	82	17	1.7
Batti	-0.546*	0.003	131	21	0.9	Hagere_selam	-0.277**	0	95	36	2.1
Gimbi	-0.253*	-0.001	72	29	2.4	Wolayita_Sodo	-0.009	-0.008***	71	18	80.1
Nekemt	0.063	-0.007***	38	27	-11.4	Jinka	-0.101	-0.008***	100	10	6.5
Bedele	-0.043	-0.006***	40	10	15.8	Bonga	-0.114	-0.003*	26	25	5.7
Metu	-0.131	-0.005**	21	16	5.0	Amaya	-0.198	-0.003	161	42	3.1
Jimma	0.233	-0.013***	60	23	-3.3	Gambella	0.012	-0.007**	20	31	-57.8
Agaro	0.117	-0.012***	88	7	-6.3	Harar	-0.810***	0.012***	141	5	0.4
Nazareth	0.299	-0.006*	109	9	-2.6	DD_Sabian	-0.204	-0.005	44	10	3.0
Shashemene	0.165	-0.011***	128	31	-4.5	AA_Akaki	1.962***	-0.025***	107	18	-0.64
Assela	-0.338	-0.001	114	11	1.7						

Note: Estimates with ***, **, and * are significant at 1, 5, and 10 percent levels of significance.

a. Beginning and end of period thresholds are expressed as percentages of average price during the respective periods in the markets paired.

Source: Results of analysis conducted using CSA data.

Appendix 11: Estimated results of TAR model with time varying thresholds, nominal price differences, Addis Ababa Kotebe and other oxen markets

Market	ρ	ρ*t	Beg. thr.(%)a	End thr. (%)a	Half Life	Market	ρ	ρ*t	Beg. thr.(%)a	End thr. (%)a	Half Life
Endaselassie	-0.424*	0	49	10	1.3	Assebe_Teferi	-0.475*	0	53	21	1.1
Axum	-2.498***	0.022***	167	39	.	Negele	-0.759***	0.007***	43	15	0.5
Adigrat	-0.852***	0.006*	168	55	0.4	Moyalle	-0.943**	0.004	96	23	0.2
Maichwe	-0.703***	0.006**	127	20	0.6	Hartishek	-0.491	-0.001	167	31	1.0
Mekelle	-0.448*	0.001	84	16	1.2	Dollo	-0.229	-0.006	133	17	2.7
Aysaita	-0.334	-0.001	74	10	1.7	Jigjiga	-1.092***	0.010**	165	25	.
Melka_werer	-0.462**	0.002	89	32	1.1	Mambuk	-1.006***	0.006*	88	35	.
Gondar	-0.505	0.001	154	38	1.0	Mender_7	-0.980***	0.006**	127	36	0.2
Kobo	-0.713***	0.005*	72	35	0.6	Assosa	-0.665	0.003	181	45	0.6
Woldia	-0.661**	0.004	59	41	0.6	Bambasi	-1.079***	0.008***	150	21	.
Dessie	-0.465*	0.002	61	49	1.1	Kemashi	-0.415**	0.002	73	56	1.3
Debre_Birhan	-0.323	-0.003	38	35	1.8	Wolkite	-0.415*	-0.002	67	36	1.3
Debre_Markos	-0.615**	0.004	116	20	0.7	Hosaena	-1.255***	0.008*	145	30	.
Bahir_Dar	-0.243	-0.003	33	29	2.5	Alaba	-1.244**	0.010*	261	54	.
Chagni	-0.791***	0.006**	100	27	0.4	Awassa	-0.361	-0.001	73	25	1.5
Batti	-0.765***	0.005	118	22	0.5	Hagere_selam	-0.649***	0.005*	147	15	0.7
Gimbi	-0.482**	0.002	51	10	1.1	Wolayita_Sodo	-0.296	-0.003	143	30	2.0
Nekemt	-0.182	-0.005*	56	40	3.4	Jinka	-0.575**	0.002	63	36	0.8
Bedele	-0.639***	0.005**	163	29	0.7	Bonga	-0.3	0.001	78	43	1.9
Metu	-0.912***	0.008**	137	17	0.3	Amaya	-0.498***	0.004*	130	47	1.0
Jimma	-0.224	-0.004	95	17	2.7	Gambella	-0.933*	0.005	74	36	0.3
Agaro	-0.692***	0.005**	49	8	0.6	Harar	-0.820**	-0.003	97	21	0.4
Nazareth	-0.446**	-0.001	48	32	1.2	DD_Sabian	-0.44	-0.004	19	12	1.2
Shashemene	-0.729**	0.005	122	29	0.5	AA_Akaki	-0.891***	0.001	25	10	0.31
Assela	-0.825***	0.006**	127	20	0.4						

Note: Estimates with ***, **, and * are significant at 1, 5, and 10 percent levels of significance.
a. Beginning and end of period thresholds are expressed as percentages of average price during the respective periods in the markets paired.
Source: Results of analysis conducted using CSA data.