Analysis of Commodity Market Integration In the Uganda Maize Market

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Abstract

This research examines the integration of commodity markets in Uganda. Weekly maize price data collected during 2001-2011in 13 regional markets is used to assess the degree to which these markets are cointegrated, i.e., market prices tend to share a long-term trend. A threshold autoregressive model is used to determine if symmetric or asymmetric threshold behavior is evident. All except one regional market is found to be linearly cointegrated with the central market. Threshold behavior only becomes apparent in the latter portion of time frame under analysis when 6 regional markets show evidence of thresholds (symmetric or asymmetric).

Chapter 1

Introduction

Markets play a central role in price discovery. When evaluating markets, researchers often attempt to determine if markets are spatially integrated. In agriculture, production and consumption markets are frequently geographically separated. A majority of production occurs in sparsely populated rural areas while a bulk of the population – hence consumption - resides in urban centers. Integrated markets will use prices to incent producers to move their goods to the consumer. Due to the spatial separation, prices must account for transportation costs to relocate the goods. Spatially separated markets are considered cointegrated when their prices share a long run trend. Arbitrage is essential to integrated markets. Spatial arbitrage is the ability to make a trade when the price differs by more than the transaction costs of trading between geographically separated markets. As Barrett (2001) describes it, "... if trade occurs and all profitable arbitrage opportunities are extinguished, prices are equalized up to the cost of commerce" (p.1). The cost of commerce may also be described as the transaction costs associated with transportation, insurance, regulatory fees, and potentially risk.

A key benefit of market integration is the ability to induce the movement of goods by the transmission of price information. This can smooth supply by redistributing relative surpluses and deficits. The value of this becomes clear when applied to food markets. If one region suffers from severe drought during the growing season, a famine can be averted by moving goods from a region that experiences relatively more abundant production. For example, if region A has a bumper crop of potatoes, more than the local consumer demands, and they are not integrated with any neighboring markets, the price of potatoes will fall – either until it finds more demand (maybe gets used as feed for livestock) or until the price is too low for the farmer to bother selling and is lost to spoilage. Let's assume region B suffered from drought and their potato crop was wiped out. If region B is isolated consumers may go hungry, as they have nowhere else to attain potatoes. However, if price information flows between the regions and they are physically able to transport the potatoes between locations, the prices will find a point such that the needs of region A's consumers are met and the farmers are paid to transport the surplus goods to region B.

Integrated markets also generate producer benefits through better transparency and more liquidity. Transparency occurs when the price and value of the good(s) are known to market's participants. Liquidity is ample when there is a sufficient number of active market buyers and sellers to facilitate trade transactions. Together these attributes tend to result in price improvements for producers by giving them power in negotiations. By knowing the value of his goods the producer can avoid being taken advantage of by an unscrupulous buyer offering a low price. Without having multiple potential trading partners, there would be no way to hold the unscrupulous buyer accountable, the producer would have to trade with him anyway. Liquidity and transparency allows the producer to be better able to manage price risk and therefore production, which in turn may provide the necessary confidence to invest in their farm through improved seeds, fertilizers and technologies.

Knowledge of the level of integration between markets, knowing if any information flows between the markets or how long it takes a price change in one market to be reflected in the other, is important for successful policy implementation. For example, the United Nations World Food Program (WFP) provides food aid through in-kind transfers (supplying food), purchasing commodities from local producers, or cash transfers. If the WFP implements its strategies assuming the markets are fully integrated when in fact they are not, there may be unintended consequences including inflation and lower prices for local producers (World Food Program P4P, 2012). Likewise, if markets are integrated the WFP, or other aid agencies, can reduce implementation costs by focusing action on specific regions and allowing the market mechanisms to distribute the goods.

Testing for market integration seems to be a simple exercise. If one had prices of homogenous products from each marketplace and the transactions costs for each corresponding time step, determining whether the two markets were integrated would be a straightforward empirical exercise. If the price in the second market exceeds the price in the first market by more than the transaction costs, one would expect trade to occur. If trading does not occur and prices do not adjust to the point where there are no profitable arbitrage opportunities, the markets are not integrated. Likewise, if trade does occur between the two markets and prices adjust to eliminate arbitrage opportunities, we consider them integrated. However, one rarely has access to transaction costs (insurance, risk, regulatory fees, and transportation), much less for each time step of the price series. Transportation is typically the most explicit component of transaction costs and a few researchers have tried to account for them specifically in market integration studies.

Hernandez-Villafuerte (2010) takes a spatial approach using distance and travel time between markets as explanatory variables for integration in the rice and soybean markets of Brazil. She finds mixed results. Distance between markets is significant for rice but is mixed for soybeans. She posits that may be due to almost 50% of soybeans produced in the country being destined for the export market (p.10), potentially making port access more important than access to neighboring regional markets. While Hernandez-Villafuerte accounts for structural breaks arising from changes in trade, economic and monetary policy that significantly affect the agriculture system of Brazil over the course of the study (signing of a regional trade agreement, for example), she acknowledges the need to account for other nonlinear components of transaction costs, possibly via threshold analysis. Furthermore, distance or travel time may not be representative of the costs of transportation depending on available infrastructure or geography. For example, if two sets of markets are each 150km apart, but one set has a mountain range between the markets while the other markets are in the plains, the transportation costs for the former will likely be greater – even though the distance is the same.

By using econometric techniques to estimate transaction costs, D’Angelo (2005) attempts to evaluate the association between the transaction costs, the adjustment parameters and changes in public infrastructure including physical infrastructure (roads and electricity), access to local media, telecommunications, a permanent market or local fair. He finds that road and electric infrastructure as well as having access to local media and telecommunications reduce transaction costs in the potato markets of Peru, thereby increasing spatial integration. However, the public infrastructure survey he uses in the analysis was only done two years apart (1997 and 1999) and he recognizes the regression equations are a bit “ad hoc.” The difficulty in obtaining detailed information on transaction costs has meant research in this area has focused on using price data alone.

The most recent data released by the Ugandan Ministry of Agriculture, Animal Industry and Fisheries shows that the agricultural sector’s contribution to national gross domestic product is 22.5% (Uganda Agricultural Planning Department, 2011)**.** Uganda’s agricultural sector is dominated by smallholder farms, which translates to 66% of the working population being in agriculture. With many livelihoods tied to the success or failure of the agricultural sector, well-functioning markets are valuable as producer benefits accompany them in terms of better prices and more liquidity. Therefore, determining the level of market integration provides important information to policy makers about the current environment.

Rashid (2004) analyzes the maize markets in Uganda after the market liberalization of the early 1990's. His study uses price data from two time periods; 1993-1994 and 1999-2000. He finds that most markets are more responsive to price changes in the latter period of the study. The northern districts are the primary exception. Insurgency in the area is a problem that is thought to hinder integration of those markets yet today.

Kiiza (2009) also examines the spatial integration of Uganda's commodity markets. He utilizes a radial framework with Kampala as the central market. Analyzing two time periods, 2000-2003 and 2004-2006, he finds that cointegration between markets increases over the two periods (the number of cointegrating vectors increases from 7 to 9). Similarly, via impulse response functions, he measures how long it takes for a price shock in one market to be reflected in the second. He finds an overall reduction in the number of weeks needed to communicate a price shock in one market to another. It is worth noting that Kiiza separates the price data in an attempt to capture potential effects of increased telecommunications infrastructure and usage in the country.

This paper proposes to expand on the prior work by: 1) analyzing the current market environment, 2) increasing the duration of the price series under analysis, 3) challenging the assumption used by Kiiza that Kampala, the primary consumption market, is the optimal market to use as the central market in a radial model approach, and 4) analyze market integration after the commodity price boom of 2006, which increased prices and price volatility in many world grain markets.

Research Objectives

The first objective of this paper is to determine if the maize markets in Uganda are spatially integrated in the presence of transaction costs. To do this, we will use a threshold auto-regressive model to determine if symmetric or asymmetric threshold behavior is evident. Symmetric thresholds elicit the same response from market participants for a positive or negative price differential of the same magnitude. Asymmetric thresholds allow for different reactions to positive and negative prices moves. This may happen when one market predominantly exports to a second market. In this case logistics systems are set up to go one way and the price differential may need to be larger to incent market participants to reverse the flow of goods.

The second objective is to determine if the number of co-integrated market pairs increases (e.g., if markets become more integrated) over time. To do so, the data will be divided into two periods, the analysis will be completed on both subsets of data, and we will compare results.

Organization

The remainder of this paper is divided into four chapters. In the next chapter we show the evolution of cointegration methods through the literature and why we choose the threshold autoregressive model for this analysis. In Chapter 3 we review the data series and describe the methods used. In Chapter 4 we report the analysis and results. In the final chapter we discuss the conclusions, potential policy implications, and follow-up research.

Chapter 2

Methodology

In this chapter we present the methods used to determine if markets are cointegrated, means to incorporate transactions costs, and the weaknesses or challenges of the existing methodology. We discuss time series properties, the Engle-Granger cointegration framework (linear cointegration) and the threshold autoregressive model. We begin by reviewing previous research on spatial integration methods.

Spatial Integration

One of the original measures of integration between two markets of the same good is price correlation. There are flaws associated with relying on this measure. If the reaction of one market is lagged to a price change in the other market, the correlation coefficient may be low in the presence of long run integration. Likewise, both markets may be affected by a third market and, therefore, they may share a trend even when they are not integrated. This simplistic view also does not address the nonstationarity that is frequent in time series. A series is stationary when the mean and standard deviation do not change through time. Regression analysis can be done directly on stationary series. Whereas regression analysis completed on non-stationary series can result in spurious correlations.

Spatial integration research has garnered much attention and focus from applied economists starting in the mid-1980s. Ravaillion (1986) acknowledged the limitations of using price correlations and proposed a dynamic model of spatial price differentials that allows for the testing of both short run and long run integration. The model forces a radial approach with one central market and N regional markets. Ravallion acknowledges that there will likely be trade and price linkages between the local markets and that by using the radial model one is "glossing over" those linkages. However he argues that this framework can be a useful way to analyze complex market structures and one need to evaluate the market structure under analysis to determine if applying the radial framework is appropriate. Ravaillion analyzes monthly price data for rice in Bangladesh from 1972-75. This includes periods of extreme volatility due to a famine in 1974. In general, Ravaillion finds weak evidence of integration. He shows that there are many obstacles to trade between the central market of Dhaka and the rural markets. This lends support for using interventionist policies, such as the government procuring food supplies and redistributing them to the necessary districts or accepting international food aid, in the case of famine because the market itself will not do so, even if there is a surplus of food in one area

Baulch (1997) acknowledges the difficulty in getting transaction cost data that matches the time steps of the price data (e.g., daily, weekly, monthly) and focuses on assessing the transaction costs for a certain point in time through what he calls "structure-conduct-performance" studies or from interviews with traders. He extrapolates transactions costs over the entirety of the time series. He uses maximum likelihood techniques to create upper and lower bounds to segment observations into 1 of 3 trading regimes; spatial price differences either equal to, less than, or greater than transaction costs. The more frequently observations fall into the latter category (the price difference is greater than transaction costs) the less integrated the market is. An advantage of this approach is the ability to look at the extent of the market integration. However, the usefulness of extrapolating transaction costs from a single point may be questionable. Additionally, the parity bounds model (PBM) proposed by Baulch does not allow for lagged effects. He acknowledges this and recommends using monthly or quarterly data.

Baulch applies the PBM model to monthly wholesale rice data from 5 of 12 regions in the Philippines during 1980-1993, and finds that the markets are highly integrated.

Near the same time that Baulch was exploring the PBM to account for transaction costs; Balke and Fomby (1997) evaluate a threshold cointegration model. They point out that in the error correction model – "This ECM describes how the variables respond to deviations from the equilibrium. One can think of the ECM as the adjustment process through which the long-run equilibrium model is maintained" (pg 627) - it is assumed prices will move toward their long run equilibrium in every time step. Yet, it is easy to envision a scenario where the price differential would have to hit a critical point before it would be worth the time and expense for traders to engage in transactions that bring the prices back to equilibrium. This threshold creates a price band within which there is little to no trading action, but once prices move outside the band trade occurs. Balke and Fomby use a two-stage approach in modeling. First, they use the Engle-Granger (1987) method to determine if the two price series are cointegrated, and then they determine if threshold behavior is evident.

Goodwin and Piggott (2001) expand on Balke and Fomby's (1997) model by allowing for asymmetric adjustments and multiple thresholds, but transaction costs are still assumed to be constant in proportional terms. Goodwin and Piggott analyze seven years of daily corn and soybean prices for four markets in North Carolina. They employ the radial approach with the largest market by volume for each commodity being the central market. They find that the threshold (price differential) increases as the distance between markets increases. They also look at asymmetrical responses. If one market is typically an exporter (producer) and another an importer (consumer), transportation systems may be set up to support that structure. Therefore, the price differential will need to be larger to induce a reversal in the trade flow. Goodwin and

Piggott only find moderate asymmetries in these highly integrated markets. Goodwin and Holt (1999) also use Balke and Fomby's methodology to analyze weekly farm, retail and wholesale U.S. beef sector prices during 1981-1998. They show that the method can be applied to vertically integrated and horizontally integrated markets.

Stationarity

Time series data is typically nonstationary, meaning the standard deviation and mean change through time. Nonstationary series can be defined as a random walk process where the value of the variable is dependent on the previous value plus an error term (white noise). This means that the previous value is the best predictor of the next value. This makes it difficult to model or predict the change.

Analysis completed on nonstationary time series can lead to spurious regression; where there appears to be a statistically significant relationship among the variables but there is no economic or fundamental meaning. A well-known example of spurious regression is from Moore (1993) where the amount of ice cream sold and the number of drowning deaths both increase, yet one would not conclude there is a causal relationship between them. The reality is that both variables increase during the warm summer months.

Time series can typically be made stationary by differencing ($X_t - X_{t-1}$). Most series are stationary after being differenced once and are then considered integrated of order 1, or I(1). To test if a time series is stationary, we test for a unit root. In its simplest form the time series relationship can be written,

$$X_t = \alpha + \beta X_{t-1} + \varepsilon_t \tag{1}$$

If β equals 1 in absolute value (H_o: $\beta = 1$), the series has a unit root and is nonstationary. The Dickey Fuller unit root test subtracts X_{t-1} from each side. We get,

$$\Delta X_t = \delta X_{t-1} + \varepsilon_t \quad (2)$$

The null hypothesis then becomes H_o: $\delta = 0$.

Dickey and Fuller (1979, 1981) expand this to account for constants and trends and then lagged differences. The latter test has become known as the Augmented Dickey-Fuller (ADF) test. The ADF test is written,

$$\Delta X_t = \alpha + \delta X_{t-1} + \Sigma \lambda \Delta X_{t-i+1} + \varepsilon_t\text{; for i,j} \quad (3)$$

Lags are used to account for serial correlation in ΔX_t. The number of lags can be chosen by any of the traditional model fit tests. In this study we will use Akaike's Information Criterion (AIC). The null hypothesis is still H_o: $\delta = 0$.

Cointegration Tests

The economic intuition behind cointegration is that when information flows between two price series, and market participants are able to act on the information, they may share a long run relationship. Assuming that each individual series is nonstationary, if there is a linear combination of the two series that is stationary, the two series are cointegrated. A simple explanation can be found in Wooldridge (2009). "If $\{y_t: t = 0,1,\ldots\}$ and $\{x_t = 0,1,\ldots\}$ are two I(1) processes, then, in general, $y_t - \beta x_t$ is an I(1) process for any number β. Nevertheless, it is possible that for some $\beta \neq 0$, $y_t - \beta x_t$ is an I(0) process, which means it has a constant mean, constant variance, and autocorrelations that depend only on the time distance between any two variables in the series, and it is asymptotically uncorrelated. If such a β exists, we say that y and x are cointegrated, and we call β the cointegration parameter" (p. 638).

This paper utilizes the Granger-Engle two-step process to test for linear cointegration. First, we estimate the long-run cointegrating parameter, β, by estimating the ordinary least squares equation:

$$y_t = \alpha + \beta x_t + \upsilon_t \tag{4}$$

The residuals (υ) are retained and tested for stationarity using the ADF unit root test. If the residuals are I(0), the two price series are cointegrated.

Threshold Autoregressive Model

The threshold autoregressive model extends the Engle-Granger method by allowing the error term, $\upsilon_{t,,}$ to follow a threshold autoregressive process. The parameters are allowed to take on different values depending on whether the previous value is above or below the threshold, τ. Therefore, the single expression

$$\upsilon_t = \rho\, \upsilon_{t-1} + u_t \tag{5}$$

becomes

$$\upsilon_t = \begin{cases} \rho_L\, \upsilon_{t-1} + e_t & \text{if } \upsilon_{t-1} \leq \tau_1 \\ \rho_M\, \upsilon_{t-1} + e_t & \text{if } \tau_1 < \upsilon_{t-1} \leq \tau_2 \\ \rho_H\, \upsilon_{t-1} + e_t & \text{if } \tau_2 > \upsilon_{t-1} \end{cases} \tag{6}$$

Two thresholds (τ_1 and τ_2) create three regimes. This allows for the possibility of asymmetric responses to price shocks, e.g., for market participants to react differently to a positive price change than to a negative price change.

Testing

According to Balke and Fomby, “Cointegration is a global characteristic of the time series while the threshold regimes are local characteristics” (p.632). This leads us to four potential situations: 1) linear cointegration and threshold behavior exists, 2) linear cointegration and no threshold behavior, 3) no linear cointegration but threshold behavior exists, or 4) no linear cointegration and no threshold behavior. The third scenario can be the most difficult to understand intuitively and exemplifies the complexities of spatial integration analysis absent true transaction costs. Essentially, the linear Engle-Granger cointegration test is not able to discern the nonlinear characteristics of the price series.

Since the distributions of the test statistics are not standard, the traditional significance tests cannot be used. Hansen (1999) notes that threshold auto-regression models with 0, 1 or 2 thresholds are nested models. He offers a bootstrap method that can be used to generate test statistics and p-values that can then be used in an F-test type evaluation. He notes it is necessary to define a minimum for the number of observations to fall in each regime created by the thresholds. Hansen chooses 10% while we use 15%. We use Hansen's method to test the statistical significance of the thresholds and by definition, the significance of a linear auto-regressive model against a one-threshold model or a two-threshold model.

Chapter 3

Data

In this chapter we discuss maize production in Uganda and the maize price time series. We also discuss challenges presented by the price series and how we have developed the price series for this analysis.

Maize Production in Uganda[1]

Maize holds a unique place in Ugandan agriculture. It is both consumed domestically as a food crop and increasingly exported as a cash crop. The 15kg per capita consumption of maize is less for Ugandans than many of their regional neighbors, who typically consume 90-100kg annually. Additional uses include sales to millers for maize flour, alcohol and animal feed.

More land in Uganda is dedicated to maize production than any other food crop with over 1 million hectares planted in the 2008-09 season. Plantains and cassava are the next largest crops with 915,877 and 871,389 hectares, respectively. Based on the 2.36 million metric tons that were produced in 2008, 47% was produced in the Eastern region, 21% in the Western region, 19% in the Central region, and 13% in the Northern region. In Table 1 we show the area and amount of production for each district. The Eastern district of Iganga is the country's largest producer of maize with 303,262 metric tons produced in the 2008/09 crop season, followed by another Eastern district market, Soroti, who produced 137 thousand metric tons. Masaka, in the Central district, produced 82,287 metric tons, making it the third largest producing area. Nakawa and Owino are markets inside Uganda's largest city, Kampala. Therefore, they do not produce any maize but are important for their role as a demand center (Uganda Agricultural Planning Department, 2011)

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[1] Historical data is from the 2011 Statistical Abstract, Uganda Agricultural Planning Department

The importance of maize as a cash crop for export continues to increase with formal exports valuing $38.8 million in 2010. There also continues to be informal trade at the border with Kenya, where demand significantly outstrips production. Therefore, the true value of maize exports from Uganda is difficult to ascertain.

Table 1. Ugandan Maize Production and Harvested Area

Market	Region	Production (UCA 2008/09 Metric Tons)	Area (UCA 2008/09 Ha)
Luwero	Central	29,849	8,284
Masaka	Central	82,287	21,798
Nakawa a/	Central		
Owino a/	Central		
Iganga	Eastern	303,262	49,333
Jinja	Eastern	18,497	12,091
Mbale	Eastern	42,644	12,916
Soroti	Eastern	137,657	15,439
Arua	Northern	11,626	6,663
Gulu	Northern	10,386	7,533
Lira	Northern	17,156	21,002
Kabale	Western	6,587	5,870
Kasese	Western	24,196	8,939
Mbarara	Western	806	836

a/ Owino and Nakawa are markets within Kampala where regional production is negligible.

Regional Market Prices

This study uses wholesale weekly price data collected during 2001-2011, for maize grain in 13 regional markets of Uganda; Central (Masaka, Nakawa, Owino), Eastern (Iganga, Jinja, Mbale, Soroti), Northern (Arua, Gulu, Lira) and Western (Kabale, Kasese, Mbarara). The price data was collected by two organizations and is expressed in Ugandan Shillings/Kg. Weekly prices from 2001-July 2008 were collected by Foodnet/International Institute of Tropical Agriculture. Starting in July 2008, prices were collected Mondays, Wednesdays and Saturdays by FIT Uganda, Ltd.

The data collected by FIT Uganda, Ltd. show only small differences in the percentage of missing observations by collection day: Monday (18.62%), Wednesday (19.05%) and Saturday (20.74%). This signals that there is not a strong bias regarding which day of the week the price is collected. To maintain continuity of the price series, we convert the 3 times per week data into a weekly price by defining the mid-point price. For example, if one price is collected in the week, it is used as the weekly price. If two prices are collected, the mid-point, or average, is used. If three prices are collected, the mid-point between the lowest and highest price is used as the weekly price.

The markets chosen for analyses are selected due to the relative completeness of their price series. However, as is typical with data sets from developing countries, there are missing observations that need to be imputed. Understanding the importance of the trend and movements of each price series; much attention is given to potential imputation methods. Four imputation methods are applied and analyzed; 1) a cubic spline curve is fit to the data, 2) a step function which uses the most recent value in the series, 3) a join function which uses a linear approximation, and 4) multiple imputation which uses the Markov Chain Monte Carlo method for arbitrary missing values. The intuition behind the multiple imputation method is that multiple values are generated for each missing observation acknowledging the uncertainty behind what the true value is (in this study, we generated 5 values for each missing observation), one then completes their analysis on each “complete” series. SAS then provides the ability to combine the results for the purposes of inference (SAS Online Documentation).

The resulting price series are compared with the original price series on the basis of standard deviation and mean, as each imputation perfectly correlates with the original price series. The results are shown in Tables 2 and 3.

Across markets, the cubic spline method frequently has the largest differences from the standard deviation and means of the original price series. The standard deviations of the multiple imputation series are similar to the original data set and, in general, closer than the series produced by the join method. However the figures for the mean are not as similar to the original series as the price series produced by the join method. After evaluating graphs of the price series, it is obvious that the multiple imputation method is introducing substantial volatility. Therefore, the missing observations in the weekly price time series are imputed with the join function using linear approximation.

Table 2. Mean of Weekly Average Maize Prices by Imputation Method, 7/01-4/11

Market	Original Series	Cubic Spline	Step	Join/Linear Approx	MI-1 a/	MI-2	MI-3	MI-4	MI-5
Arua	397.00	391.88	393.91	393.47	399.83	397.35	400.93	396.97	400.82
Gulu	310.08	258.09	292.80	331.15	319.12	323.16	326.94	325.21	327.57
Iganga	290.12	255.09	281.71	305.15	305.49	302.66	298.77	299.60	302.95
Jinja	311.37	309.99	298.22	313.47	321.15	321.03	319.70	320.62	322.80
Kabale	391.99	383.46	385.32	384.01	394.89	398.69	395.47	400.95	391.59
Kasese	312.56	324.24	348.53	339.02	333.08	327.54	326.79	334.60	328.63
Lira	342.55	340.32	339.89	340.54	345.56	346.23	349.13	342.04	344.89
Luwero	368.33	396.91	343.10	410.04	404.76	403.77	399.74	411.46	408.32
Masaka	326.04	329.92	324.67	326.45	327.21	331.96	327.08	329.36	327.72
Mbale	313.98	341.53	302.42	327.35	328.85	327.45	324.81	327.82	326.95
Mbarara	458.09	466.39	450.87	456.84	464.48	461.75	464.16	468.11	463.20
Nakawa	428.15	428.77	426.22	425.99	411.26	407.85	406.69	412.64	412.85
Owino	356.66	357.54	357.29	356.69	346.48	347.29	344.71	348.36	345.05
Soroti	321.63	318.02	318.87	318.41	322.87	323.33	321.91	322.76	322.63

a/ Multiple imputation

Table 3. Standard Deviation of Weekly Average Maize Prices by Imputation Method, 7/2001-4/2011

Market	Original Series	Cubic Spline	Step	Join	MI-1 a/	MI-2	MI-3	MI-4	MI-5
Arua	164.72	164.10	163.82	163.22	161.99	162.90	162.84	164.52	164.02
Gulu	201.77	224.29	185.54	192.79	188.32	191.22	194.60	194.25	196.74
Iganga	147.91	168.16	137.25	142.10	146.75	145.01	144.35	141.62	142.88
Jinja	167.64	154.17	154.85	154.14	162.39	164.32	162.00	161.03	162.17
Kabale	234.74	222.67	222.85	222.87	231.38	227.05	226.59	230.12	227.35
Kasese	219.31	249.62	254.42	232.82	223.47	216.60	218.59	221.09	217.76
Lira	230.00	225.00	223.85	224.82	229.51	224.85	227.69	227.32	227.28
Luwero	224.01	227.17	203.81	221.79	221.60	216.35	213.22	222.14	222.40
Masaka	175.03	178.57	169.86	172.06	175.13	173.95	171.46	172.21	172.91
Mbale	153.71	163.39	149.09	150.18	147.30	147.27	148.40	148.53	148.94
Mbarara	283.32	301.98	273.26	278.09	278.47	275.41	277.28	278.59	278.08
Nakawa	211.85	208.41	207.32	207.14	214.08	214.23	214.96	210.22	213.06
Owino	150.25	149.09	149.00	148.25	150.76	151.85	151.05	152.07	150.63
Soroti	155.62	152.56	152.30	152.32	152.44	152.96	154.13	153.32	153.85

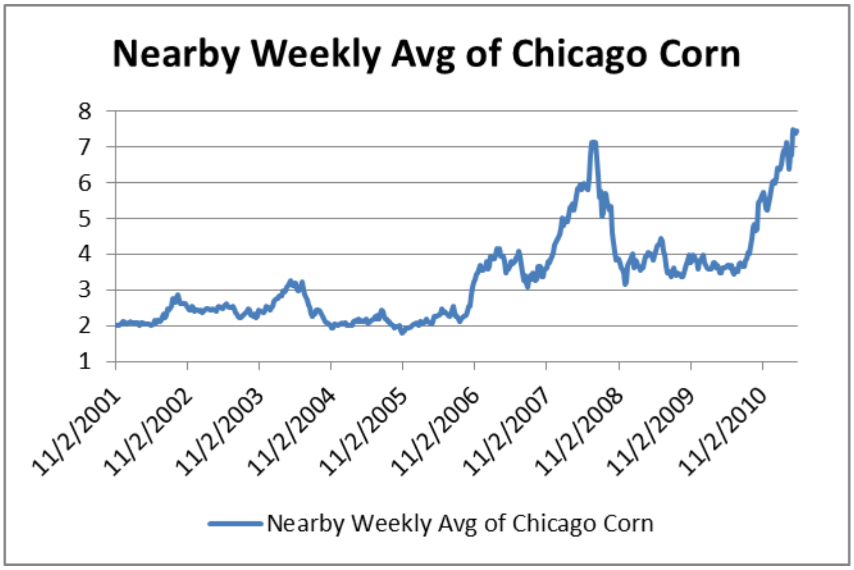
a/ Multiple imputation

Table 4. Percentage of Missing Weekly Maize Price Observations

Market	Data period 11/2001-12/2005 (n = 215)	Data period 7/2008-4/2011(n = 145)
Arua	4.19%	2.76%
Gulu	11.63%	15.86%
Iganga	2.79%	2.76%
Jinja	3.72%	2.07%
Kabale	11.63%	8.28%
Kasese	1.86%	28.97%
Lira	6.05%	4.83%
Luwero	2.79%	30.34%
Masaka	5.58%	3.45%
Mbale	1.86%	6.90%
Mbarara	9.77%	14.48%
Nakawa	0.93%	1.38%
Owino	0.47%	1.38%
Soroti	4.19%	1.38%

The analysis begins by using the price series from 2001-2011. The price series are split into two sub-periods after finding that many series were I(0). The number of missing observations is greatest during 2006-2008, when the reporting agencies changed. After we exclude that period, generally the price series for both time periods are integrated of order (1). This gives us more confidence that the method of imputation is suitable for the shorter durations. The complexity in removing the 2006-08 data is that it encompasses the period of extreme volatility associated with the global commodity boom (see Figure 1). We report the average weekly price of corn traded on the Chicago Mercantile Exchange (CME), which is frequently used as the benchmark for world corn prices.

Figure 1. Weekly average CME corn prices, 2001-2010.



It appears that the risk associated with losing that information is less than the data integrity risk. The 2006-2008 period could also be viewed as a structural break which is a change in the mean, variance and/or standard deviation over time. In this case, the change in the prices levels may be driven the large scale production of biofuels increasing demand on corn, the increase in speculative investing in commodities, and the overall global economic state. A comparison of the level of market integration between the two time periods is a useful endeavor in itself. Therefore, we complete the threshold cointegration analysis on two time periods: November 2001-December 2005 and July 2008-April 2011.

Tables 5 and 6 contain the summary statistics on the two time periods, with the prices in levels and after taking the log. Comparing the range of prices in the first and second time periods, one can see the range and standard deviation is much larger from 2008-2011. In the next chapter this will be displayed visually in price charts. Using the U.S. futures markets as a proxy for world agricultural prices, we would see a similar pattern. Although there is controversy over the reasons, which include; increasing demand from developing countries, weather related supply problems, biofuels policies that create a demand pull away from food use, and increase in speculative money invested in the commodity markets, price volatility has increased in global commodity markets the past few years, and we see this in the regional markets of Uganda.

Table 5. Maize Price Summary Statistics: 11/01-12/05

	Prices in Levels				Log Prices			
Market	Min	Max	Mean	Std Dev	Min	Max	Mean	Std Dev
Arua	90	600	323.21	117.66	4.50	6.40	5.69	0.45
Gulu	100	380	209.30	51.05	4.61	5.94	5.31	0.26
Iganga	60	350	224.35	65.94	4.09	5.86	5.36	0.37
Jinja	70	380	232.49	70.62	4.25	5.94	5.39	0.36
Kabale	100	450	262.64	75.37	4.61	6.11	5.52	0.33
Kasese	60	400	217.86	73.99	4.09	5.99	5.31	0.40
Lira	40	370	226.30	66.57	3.69	5.91	5.36	0.37
Luwero	60	650	271.99	79.82	4.09	6.48	5.55	0.37
Masaka	70	540	261.30	92.99	4.25	6.29	5.48	0.45
Mbale	85	430	247.74	69.69	4.44	6.06	5.46	0.33
Mbarara	80	500	268.65	97.00	4.38	6.21	5.51	0.42
Nakawa	100	480	276.20	76.98	4.61	6.17	5.57	0.33
Owino	95	490	261.59	74.51	4.55	6.19	5.52	0.33
Soroti	85	450	239.67	71.87	4.44	6.11	5.43	0.35

Table 6. Maize Price Summary Statistics, 7/2008 - 4/2011

	Prices in Levels				Log Prices			
Market	Min	Max	Mean	Std Dev	Min	Max	Mean	Std Dev
Arua	300	1125	557.93	164.64	5.70	7.03	6.28	0.32
Gulu	150	1250	549.89	206.06	5.01	7.13	6.23	0.43
Iganga	190	700	445.67	148.45	5.25	6.55	6.03	0.38
Jinja	160	1000	481.93	170.26	5.08	6.91	6.11	0.40
Kabale	290	1400	619.86	282.46	5.67	7.24	6.34	0.42
Kasese	150	1200	629.86	247.17	5.01	7.09	6.35	0.47
Lira	180	1500	589.85	287.87	5.19	7.31	6.27	0.48
Luwero	200	1200	680.40	196.26	5.30	7.09	6.46	0.38
Masaka	150	1400	498.07	204.42	5.01	7.24	6.12	0.45
Mbale	200	900	487.69	161.21	5.30	6.80	6.13	0.35
Mbarara	400	1250	854.00	176.67	5.99	7.13	6.73	0.22
Nakawa	300	1125	670.38	187.07	5.70	7.03	6.47	0.28
Owino	225	900	490.31	161.11	5.42	6.80	6.13	0.36
Soroti	250	900	488.81	150.12	5.52	6.80	6.14	0.31

Chapter 4

Analysis and Results

In this chapter we present the results of the threshold cointegration analysis for the maize markets of Uganda. The results include a discussion of stationarity tests for all markets included in the study for the time frames of November 2001 to December 2005 and July 2008 to April 2011. We then present results from the Engle-Granger linear cointegration framework and a threshold auto regression model, using both Owino and Iganga as central markets in a radial model approach.

Analysis

Before analyzing the price series we take the log of the prices and then test the price series in each market and in each period for stationarity. We use the Augmented Dickey-Fuller test, which incorporates the possibilities of autoregressive lags, a constant but nonzero mean, and a trend. Incorporating potential lags gives us a robust view of stationarity for each series.

The northern regional markets (Arua, Gulu and Lira) and the eastern markets (Iganga, Jinja, Mbale and Soroti) are determined to be I(1)[2] for both periods. Of the Western region, Kabale, Kasese and Mbarara, only Kabale is I(1) for both periods. Kasese market shows some evidence of stationarity in the first period (2001-2005), and strong evidence that it is I(0) in the second period (2008-2011). Kasese is not a large maize producing district. It is estimated that just 24,196 metric tons were produced in 2008-2009, but more importantly it has the most missing observations during 2008-2011. This forces the use of imputed values for nearly 29% of the weekly price observations. Since this may mask the true time series properties of the price series, we remove the Kasese market from the cointegration analysis. The Mbarara market shows

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[2] I(0) denotes a price series that is stationary. I(1) denotes a price series (X) that becomes stationary after being first differenced ($X_t - X_{t-1}$).

a similar pattern and is the smallest market in our sample producing a mere 806 metric tons in 2008-09. It also has more missing weekly price observations than average 9.77% during 2001-2005 and 14.48% during 2008-2011. We remove the Mbarara market from analysis in the second period.

The central region of Uganda includes the capital and largest city, Kampala. The Owino and Nakawa markets are within Kampala, while Masaka lies approximately 130 kilometers to the South. These Kampala markets are the largest consumption markets, which should make them relatively liquid, although volume data is not available to confirm this.

The Kampala district is used as the central market in a previous study by Kiiza (2009). Kiiza employs the Johansen cointegration framework to determine the number of cointegrating vectors for four staple commodities in Uganda during two sub-periods: 2000-2003 and 2004-2006. He finds the number of cointegrating vectors increases and the time it takes for regional markets to absorb a price shock from the central market decreases from one sub-period to the next. The two sub-periods are used to assess the effect of an increase in telecommunications usage on market prices.

The Nakawa market shows strong evidence of stationarity in the first period and it is determined to be an I(0) process. The market is removed from the first period cointegration analysis, while Owino market shows some evidence of stationarity. Both are I(1) processes in the second period of analysis and the Masaka market is an I(1) process throughout.

This study employs Ravallion's radial model for cointegration analysis. The radial approach uses a central market and tests the cointegration between each regional market and the central market. Initially, we use Owino as the central market. We apply the Engle-Granger approach to cointegration by regressing the central market price series on each regional market price series, then running the Augmented Dickey Fuller test on the residuals. If the residuals are stationary, I(0), the price series are considered cointegrated.

Owino as the Central Market

Using Owino as the central market, all market pairs are linearly cointegrated at the 5% level of significance. In Table 7 we display the OLS estimates of the cointegrating relationship, where β is known as the cointegrating vector. Owino is always used on the right-hand side of the least squares equation as the independent variable. Since the prices on both sides of the equation are the natural log of the original price, β is interpreted as a price elasticity. In the first period, the values for β range from 0.63 for Gulu in the Northern region to 0.98 for Iganga in the Eastern region, meaning that the percentage price change in Owino explains 63% of the price change in Gulu, for example. Generally, β is higher for markets in the Central and Eastern regions compared to the Northern and Western regions. The Eastern region is the largest producer and the Central region has the most dense population center. Therefore, it should be the largest consumer. That may explain the higher betas.

Moving to the second period of analysis, 2008-2011, the range of β is much greater, from 0.302 for Mbarra in the Western region to 0.972 for Jinja in the Eastern region. The R-squared also decreases between the periods, generally. This isn't surprising given the increase in volatility previously discussed. Few cointegration studies include discussion of the cointegrating vectors, since the data is nonstationary and, therefore, standard testing procedures are not valid. We note that Goodwin and Piggott (2001) include the OLS estimates of the cointegrating relationships of the corn and soybean markets in North Carolina. The range of cointegrating vectors they find is narrower: 0.9018 to 1.0119. Their analysis is in more developed markets, so the results are not surprising and their estimates are difficult to compare to the maize markets in Uganda.

Table 7. OLS Estimates of Cointegrating Relationship with Owino as the Central Market

		Data (11/2001 to 12/2005)				Data (7/2008 to 4/2011)			
Market	Region	α	β	Model Stats		α	β	Model Stats	
Arua	Northern	1.05	0.84	38.7%	R2	3.98	0.37	17.7%	R2
	Std Errors	0.40	0.07	135.8	Fstat	0.41	0.07	32.0	Fstat
	Pvalue	0.01	0.00	0.0		0.00	0.00	0.0	
Gulu	Northern	1.84	0.63	62.4%	R2	0.35	0.96	65.7%	R2
	Std Errors	0.18	0.03	356.3	Fstat	0.35	0.06	276.3	Fstat
	Pvalue	0.00	0.00	0.0		0.32	0.00	0.0	
Iganga	Eastern	-0.03	0.98	76.7%	R2	0.12	0.63	82.5%	R2
	Std Errors	0.20	0.04	703.9	Fstat	0.23	0.04	679.8	Fstat
	Pvalue	0.89	0.00	0.0		0.59	0.00	0.0	
Jinja	Eastern	0.02	0.97	82.0%	R2	0.14	0.97	79.3%	R2
	Std Errors	0.18	0.03	977.4	Fstat	0.25	0.04	552.6	Fstat
	Pvalue	0.92	0.00	0.00		0.57	0.00	0.0	
Kabale	Western	1.73	0.69	46.8%	R2	2.29	0.66	33.2%	R2
	Std Errors	0.28	0.05	189.4	Fstat	0.49	0.08	69.6	Fstat
	Pvalue	0.00	0.00	0.00		0.00	0.00	0.0	
Lira	Northern	0.06	0.96	73.5%	R2	-0.73	0.90	45.8%	R2
	Std Errors	0.22	0.04	594.1	Fstat	0.50	0.08	122.5	Fstat
	Pvalue	0.80	0.00	0.00		0.15	0.00	0.0	
Masaka	Central	-0.61	1.10	67.5%	R2	0.43	0.93	56.0%	R2
	Std Errors	0.29	0.05	444.7	Fstat	0.42	0.07	184.2	Fstat
	Pvalue	0.04	0.00	0.00		0.30	0.00	0.0	
Mbale	Eastern	0.67	0.87	76.3%	R2	0.98	0.84	73.6%	R2
	Std Errors	0.18	0.03	688.0	Fstat	0.26	0.04	401.5	Fstat
	Pvalue	0.00	0.00	0.00		0.00	0.00	0.0	
Mbarara	Western	1.52	0.72	31.8%	R2				
	Std Errors	0.72	0.07	100.8	Fstat				
	Pvalue	0.00	0.00	0.00					
Nakawa	Central					2.39	0.67	71.6%	R2
	Std Errors					0.21	0.03	364.6	Fstat
	Pvalue					0.00	0.00	0.0	
Soroti	Eastern	0.27	0.94	79.7%	R2	1.89	0.69	64.1%	R2
	Std Errors	0.18	0.03	839.3	Fstat	0.27	0.04	258.0	Fstat
	Pvalue	0.14	0.00	0.00		0.00	0.00	0.0	

Threshold Autoregressive Model Results for the Owino Market

The threshold autoregressive (TAR) model extends the Engle-Granger method by allowing the error term to follow a threshold autoregressive process. The TAR model allows the parameters to take on different values depending if the previous value is above or below a certain threshold. Simply, the thresholds create a range to represent transaction costs. Outside the band, markets are likely to react differently than inside the band. If one thinks of transaction costs solely as transportation, one can see how market participants will behave differently. If the price differential between markets is less than the transportation cost of moving the good from one market to the other, we do not expect trade to occur. If the price differential is greater than the transportation cost (or threshold), we do expect trade to occur as there is an opportunity to make a profit by moving the good. Estimating two thresholds allows for asymmetric reactions. For example, if a country exports a large percentage of their crop, the transportation system may be set up to move goods from the center of the country to the export port. Therefore the price differential may need to be larger to incent market participants to reverse that flow.

The TAR model is estimated from the residuals of the OLS model that was estimated between the central market and each regional market. The lag length used in the TAR model is chosen by minimizing the AIC of the autoregressive model on the residuals. Hansen's test is then used to assess if threshold behavior is present. Similar to a standard F-test, it tests the model in its entirety – a simple autoregressive model versus a model with one threshold, versus a model with two thresholds.

Looking at the top entry in Table 8 for Arua, the Hansen statistic for an AR model versus a TAR model with one threshold is 5.36 with a p-value of 0.526. The next row shows a Hansen statistic and p-value of 12 and 0.482, respectively, for an AR model versus a TAR model with two thresholds. Based on the Hansen test statistics and associated p-values, we do not have evidence that threshold behavior is evident between the Arua market and the Owino market.

Using Hansen's statistic to evaluate the one and two threshold model against an autoregressive model, we determine that no market pairs exhibit threshold behavior in the first period (November 2001-December 2005) at a 5% significance level (see Table 8). We do find that Kabale and Mbarara show symmetric threshold behavior at the 10% level of significance.

In Table 9 we report results for the second period (July 2008-April 2011). Arua, Iganga, Jinja, and Masaka show threshold behavior at the 5% level of significance. The Gulu market shows threshold behavior at the 10% level. Three markets exhibit asymmetric threshold behavior. They are: Iganga, Masaka and Arua. Recall, in the first data period, the Hansen test in Table 8 (November 2001 – December 2005), for comparing a simple autoregressive model versus a one or two threshold model, produced p-values greater than 0.5 for these three markets. This meant that there is no significant evidence to conclude that threshold behavior was evident. When we look at the second data period (from July 2008 to April 2011), the p-values for the same tests are less than 0.05 and we determine the markets exhibit asymmetrical threshold behavior.

Table 8. Threshold Autoregression model for Maize with Owino as the Central Market, November 2001- December 2005

Market-Region	Optimal lag length /a	Th1/b	Th2/b	SSR	Proportion of Observations In Each Regime/c			Hansen's Test Statistic	p-value
Arua - Northern	1	-0.270	0.233	3.836	25.23	43.46	31.31	5.36	0.526
								12.00	0.482
Gulu - Northern	1	-0.028	0.040	2.377	35.98	23.36	40.65	3.59	0.794
								10.69	0.526
Iganga - Eastern	1	-0.166	0.276	3.602	16.82	33.64	49.53	1.98	0.941
								6.51	0.928
Jinja - Eastern	1	-0.113	-0.007	2.955	16.82	27.1	56.07	3.17	0.85
								7.64	0.83
Kabale - Western	1	-0.055	0.012	3.650	35.98	16.85	47.2	12.34	**0.052**
								17.51	0.122
Lira - Northern	1	-0.140	-0.054	3.722	16.36	18.22	65.42	6.41	0.336
								8.41	0.774
Masaka - Central	3	0.112	0.246	4.173	65.57	19.81	14.62	13.79	0.122
								23.61	0.178
Mbale - Eastern	1	-0.116	0.013	2.327	19.16	28.06	52.8	4.38	0.652
								10.18	0.648
Mbarara - Western	12	-0.240	0.318	2.013	17.24	64.53	18.23	33.08	**0.09**
								59.97	0.275
Soroti -Eastern	4	-0.100	0.125	2.864	23.22	57.82	18.93	12.87	0.274
								16.80	0.792

/a The lag length is chosen by minimizing the AIC of an autoregressive model on the residuals.
/b Th1 and Th2 are the threshold values chosen by minimizing the SSR (sum of squared residuals).
/c A minimum of 15% of observations was required to fall into each regime

Table 9. Threshold Auto regression model for Maize with Owino as the Central Market: July 2008-April 2011

Market-Region	Opt. lag length /a	Th1 /b	Th2 /b	SSR	Prop of Observations In Each Regime /c			Hansen's Test Statistic	Pvalue
Arua – Northern	2	-0.084	0.146	2.045	32.17	34.27	33.57	21.42	**0.006**
								32.97	**0.018**
Gulu – Northern	4	-0.194	-0.052	4.599	17.02	26.24	56.74	17.78	**0.092**
								29.46	0.242
Iganga – Eastern	3	0.011	0.114	1.490	52.11	24.65	23.24	18.61	**0.046**
								31.91	**0.05**
Jinja – Eastern	1	0.017	0.138	3.111	52.08	31.25	16.67	13.51	**0.026**
								17.45	0.164
Kabale – Western	1	-0.040	0.217	3.920	57.64	22.22	20.14	4.57	0.598
								9.44	0.708
Lira – Northern	1	-0.311	0.340	3.400	15.97	68.06	15.97	4.21	0.68
								7.80	0.826
Masaka – Central	2	-0.273	0.223	3.537	16.78	67.13	16.08	26.84	**0.004**
								37.73	**0.008**
Mbale – Eastern	1	0.035	0.136	1.908	56.94	21.53	21.53	9.15	0.128
								14.42	0.282
Nakawa – Central	2	0.040	0.132	1.758	65.03	15.38	19.58	8.14	0.358
								16.25	0.388
Soroti –Eastern	4	-0.098	0.191	1.144	35.46	47.52	17.02	19.86	**0.062**
								29.17	0.186

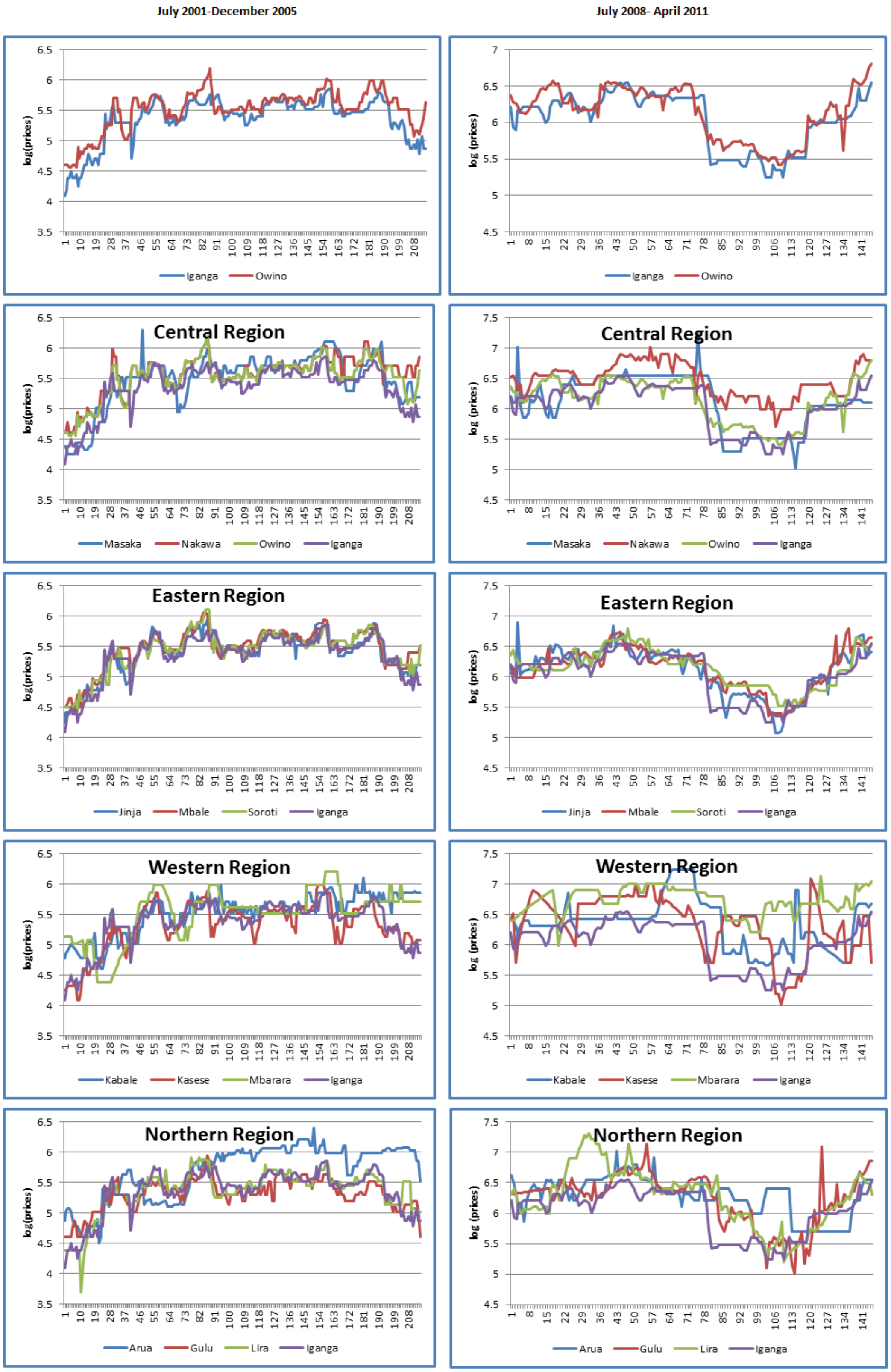
/a The lag length is chosen by minimizing the AIC of an autoregressive model on the residuals.
/b Th1 and Th2 are the threshold values chosen by minimizing the SSR (sum of squared residuals).
/c A minimum of 15% of observations was required to fall into each regime

Iganga as the Central Market

Nakawa and Owino are only 5km apart, and Nakawa is clearly an I(0) process in the first period of analysis. This leads us to question if using a Kampala market as the central market is an accurate reflection of the market structure for maize.

The price charts in Figure 2 suggest the markets in the Eastern region follow the same path. The Eastern region is also the largest producing region, with Iganga alone producing 44% of the nation’s maize in 2008-09. The first set of price charts show that Owino and Iganga also follow similar paths. The combination of these factors leads us to conduct the analysis a second time using Iganga, the largest production region, as the central market in the radial framework rather than Owino, which is the largest consumption area. Previous research has used both consumption and production markets as the central market in the radial framework. Ravallion (1986) used Dhaka as the central market, which was largest city (consumption center) in Bangladesh and the transportation system was built to serve the city (p. 106). Whereas Goodwin and Piggot’s (2001) analysis of corn and soybean markets in North Carolina used the largest market in terms of volume, as the central market (p. 305). In summary, there doesn’t appear to be theoretical preference but rather an acknowledgement that they dynamics of each market are unique and may result in supply push or a demand pull.

Figure 2: Maize Prices by Region and Data Period



Based on the Engle-Granger cointegration framework, all regional markets except Arua are linearly cointegrated with Iganga at the 5% level. Arua is in the north of Uganda on the border with Democratic Republic of Congo. This is an area that struggles with instability and political violence. It is likely that informal cross-border trade has greater effect on the prices in Arua. Therefore, it is not surprising that it is not cointegrated with Iganga. In Table 10 we report the cointegrating relationships between Iganga and the regional markets. The range of β is from 0.56 to 1.02 in the first period, for Kabale in the Western region and Masaka in the Central region, respectively. During 2008-2011, the estimated βs range from0.31 for Mbarra to 0.98 for Masaka. Generally, β is "higher" for the Eastern and Central markets and the R-square statistic follows a similar pattern. This is evidence that price changes in the Iganga market have a greater effect on the markets in the Central and Eastern regions than in the Western and Northern regions.

Threshold Autoregressive Model Results for the Iganga Market

Using the TAR framework and Hansen's method, we determine that at the 5% level, no market pairs exhibit threshold behavior in the first period. In the second period of analysis, six market pairs exhibit asymmetric threshold behavior including; Arua (Northern), Gulu (Northern), Owino (Central), Jinja (Eastern) Masaka (Central) and Mbale (Eastern). Of the markets that do not exhibit threshold behavior, two of them, Lira and Kabale are small producers which are outside the Eastern region where the central market of Iganga is located.

One could theorize that because Lira and Kabale are linearly cointegrated with Iganga, the general price levels in those markets are affected by Iganga. But Lira and Kabale consume a majority of the local production or have a geographical barrier to trade, making transaction or transportation costs either more volatile or less important overall. Therefore, there are no significant or consistent thresholds. The surprising result is that Soroti, a larger producing market in the Eastern region, does not exhibit threshold behavior. By reviewing Figure 2, we can see there is approximately a 30-week period when prices in Soroti seem to separate from the movements of the prices in Iganga. We do not know if there are local dynamics that caused the temporary disconnect or if this is a data reporting error.

Reviewing the threshold estimates and proportion of observations in each regime, there are few discernable patterns between time periods or regions. However comparing across markets for the same time periods, the threshold estimates tend to be “smaller” or “narrower” when Iganga is used as the central market versus Owino. Using Masaka as an example, the threshold estimates are -0.273/.223 when Owino is used as the central market, but are -0.135/.043 when Iganga is used as the central market. The pattern doesn’t hold for each comparison, but could be an additional piece of evidence suggesting the Iganga is the appropriate central market.

Table 10. OLS Estimates of Cointegrating Relationship for Maize with Iganga as the Central Market

		11/2001 to 12/2005				7/2008 to 4/2011			
Market	Region	α	β	Model Stats		α	β	Model Stats	
Arua	Northern	1.84	0.72	0.35	R2	4.35	0.32	0.14	R2
	Std Errors	0.36	0.07	116	Fstat	0.39	0.06	25	Fstat
	Pvalue	0.00	0.00	0.00	Pvalue	0.00	0.00	0.00	Pvalue
Gulu	Northern	2.03	0.61	0.74	R2	0.71	0.91	0.67	R2
	Std Errors	0.13	0.03	602	Fstat	0.32	0.05	297	Fstat
	Pvalue	0.00	0.00	0.00	Pvalue	0.03	0.00	0.00	Pvalue
Owino	Eastern	1.30	0.79	0.77	R2	0.96	0.86	0.83	R2
	Std Errors	0.16	0.03	704	Fstat	0.20	0.03	680	Fstat
	Pvalue	0.00	0.00	0.00	Pvalue	0.00	0.00	0.00	Pvalue
Jinja	Eastern	0.52	0.91	0.89	R2	0.59	0.91	0.79	R2
	Std Errors	0.12	0.02	1690	Fstat	0.24	0.04	0.00	Fstat
	Pvalue	0.00	0.00	0.00	Pvalue	0.01	0.00		Pvalue
Kabale	Western	2.53	0.56	0.38	R2	2.42	0.65	0.35	R2
	Std Errors	0.26	0.05	134	Fstat	0.44	0.07	79	Fstat
	Pvalue	0.00	0.00	0.00	Pvalue	0.00	0.00	0.00	Pvalue
Lira	Northern	0.57	0.90	0.79	R2	0.83	0.90	0.51	R2
	Std Errors	0.17	0.03	806	Fstat	0.44	0.07	154	Fstat
	Pvalue	0.00	0.00	0.00	Pvalue	0.06	0.00	0.00	Pvalue
Masaka	Central	0.01	1.02	0.72	R2	0.19	0.98	0.71	R2
	Std Errors	0.24	0.04	544	Fstat	0.32	0.05	352	Fstat
	Pvalue	0.97	0.00	0.00	Pvalue	0.56	0.00	0.00	Pvalue
Mbale	Eastern	1.12	0.81	0.83	R2	1.50	0.77	0.69	R2
	Std Errors	0.14	0.03	1010	Fstat	0.26	0.04	320	Fstat
	Pvalue	0.00	0.00	0.00	Pvalue	0.00	0.00	0.00	Pvalue
Mbarara	Western	2.48	0.57	0.24	R2				
	Std Errors	0.37	0.07	69	Fstat				
	Pvalue	0.00	0.00	0.00	Pvalue				
Nakawa						2.74	0.62	0.69	R2
						0.21	0.03	326	Fstat
						0.00	0.00	0.00	Pvalue
Soroti	Eastern	0.85	0.85	0.82	R2	2.19	0.65	0.64	R2
	Std Errors	0.14	0.03	1005	Fstat	0.25	0.04	260	Fstat
	Pvalue	0.00	0.00	0.00	Pvalue	0.00	0.00	0.00	Pvalue

Table 11. Threshold Auto-regression Model for Maize with Iganga as the Central Market, November 2001 – December 2005

Market-Region	Opt lag length	Th1	Th2	SSR	Prop of Observations In Each Regime			Hansen's Test Statistic	Pvalue
Arua - Northern	6	0.018	0.105	2.784	63.16	21.53	15.31	15.05	0.40
								34.13	0.40
Gulu - Northern	1	-0.001	0.142	2.005	53.27	31.31	15.42	11.41	**0.06**
								15.47	0.23
Owino - Central	1	-0.114	-0.025	2.954	53.27	31.31	15.42	2.69	0.92
								5.05	0.99
Jinja - Eastern	2	-0.042	0.054	2.206	26.76	44.13	29.11	5.38	0.67
								8.22	0.94
Kabale - Western	4	-0.193	-0.042	3.103	18.01	23.22	58.77	11.30	0.46
								21.14	0.54
Lira - Northern	1	-0.119	-0.015	2.993	19.63	27.1	53.27	2.00	0.96
								13.16	0.36
Masaka - Central	1	-0.226	-0.074	4.488	16.36	17.29	66.35	6.25	0.36
								11.54	0.53
Mbale - Eastern	6	-0.085	-0.028	1.595	22.49	16.27	61.24	13.71	0.49
								27.21	0.60
Mbarara - Western	1	-0.015	0.260	2.971	41.12	37.38	21.5	17.95	0.73
								35.34	0.91
Soroti -Eastern	1	-0.071	0.002	2.388	30.84	18.69	50.47	1.68	1.00
								4.14	1.00

/a The lag length was chosen by minimizing the AIC of an autoregressive model on the residuals.
/b Th1 and Th2 are the threshold values chosen by minimizing the SSR (sum of squared residuals).
/c A minimum of 15% of observations was required to fall into each regime

Table 12. Threshold Auto-regression Model for Maize with Iganga as the Central Market, July 2008 – April 2011

Market-Region	Opt lag length	Th1	Th2	SSR	Prop of Observations In Each Regime			Hansen's Test Statistic	Pvalue
Arua - Northern	1	-0.050	0.095	2.255	40.28	11.81	47.91	15.73	**0.010**
								24.13	**0.018**
Gulu - Northern	7	-0.169	-0.057	2.720	18.12	19.57	62.31	52.90	**0.000**
								92.44	**0.004**
Owino - Central	3	-0.116	0.006	1.263	21.13	31.69	47.18	28.20	**0.000**
								48.72	**0.000**
Jinja - Eastern	3	-0.031	0.067	2.002	44.37	17.61	38.02	36.68	**0.000**
								52.08	**0.000**
Kabale - Western	3	-0.149	0.281	3.527	29.58	54.93	15.49	12.87	0.166
								22.54	0.328
Lira - Northern	1	-0.177	-0.081	2.400	29.17	18.06	52.77	3.74	0.792
								7.09	0.896
Masaka - Central	1	-0.135	0.043	3.351	24.31	31.94	43.75	18.44	**0.004**
								24.83	**0.022**
Mbale - Eastern	1	0.002	0.110	1.641	54.17	15.28	30.55	21.96	**0.004**
								24.84	**0.016**
Nakawa - Central	1	0.015	0.130	1.885	56.94	22.22	20.84	3.34	0.812
								11.93	0.442
Soroti -Eastern	1	-0.154	0.103	1.119	25	44.44	30.56	7.09	0.282
								12.48	0.424

The results of the threshold cointegration analysis are similar whether we use Owino or Iganga as the central market. The market pairs, except Iganga and Arua, are linearly cointegrated at the 5% level. No market pairs exhibit threshold behavior in the earlier time period, regardless of the central market. In both scenarios, we see threshold behavior in the second period for four market pairs using Owino, and six market pairs using Iganga. In the latter data period we detect more asymmetric threshold behavior using Iganga. Given the similarity of the pattern of both price series, it is not surprising the results are comparable and gives us some confidence in the results of the analysis.

There are a few reasons to prefer the Iganga model results. First, in the latter period of analysis when volatility can be seen in the price series, the prices of the Eastern region diverge much less from each other. Second, Nakawa and Owino are only 5km apart within Kampala, yet their prices diverge materially at points. Although there may be local characteristics causing the divergence, we remain skeptical of this apparent disconnect. If Owino is in fact the central market, would it not first be integrated with the market immediately next door? Consequently, we will focus the conclusion on results using Iganga as the central market in this radial framework.

Chapter 5

Conclusions

The objectives of this paper are to determine if the maize markets of Uganda are spatially integrated in the presence of transaction costs. First, we want to determine if they exhibit symmetric or asymmetric threshold behavior by using a threshold autoregressive model. Second, we want to determine if the number of cointegrated market pairs increases over time. Similar to Kiiza (2009), we find that all market pairs (with the exception of Arua) are linearly cointegrated. No markets demonstrate threshold behavior, symmetric or asymmetric, in the first time period (November 2001-December 2005). In the second period (July 2008 - April 2011), six market pairs exhibit symmetric and asymmetric threshold behavior.

Rashid (2004) analyzed the maize markets of Uganda following the market liberalization of the early 1990s. He hypothesized that traders needed to learn new skills, such as arbitrage, before they are able to take advantage of the new market structure. This is what we see in this study. Through the decade under analysis, the market develops and market participants are better able to execute trades and thereby create noticeable transaction bands. The increase in volatility in the latter period may have had a hand in forcing market participants to more closely monitor and control transaction costs to maintain profitability. Based on the market pairs that are cointegrated, we can also conclude that proximity to the main area of production is beneficial to being integrated with the market. This may be particularly important in Uganda since Iganga produces such a large portion – 44% - of the country’s maize, thereby having a significant impact on price dynamics. In a country where production is more evenly dispersed, primary consumption centers may have more impact on price dynamics.

Our conclusions about the causes of market integration are based on common sense behaviors. Intuitively, we expect an efficient and effective logistic system (roads, rail and ports), quality and appropriately scaled storage, transparent and attainable market information, and a suitably knowledgeable work force contributes to market integration. However, governments have finite resources and would benefit from knowing which factor(s) provide the greatest return on capital in contributing to the integration of markets.

Only two studies have attempted to quantify the impact of changes in infrastructure in the cointegration framework. Goletti, *et al.* (1995) was the first. He found conflicting results on the sign and significance of many individual determinants depending on which measure of integration was used. The advances in econometric techniques would hopefully overcome the conflicting results. More recently, D'Angelo (2005) finds that an increase in roads reduces transaction costs between potato markets in Peru. Electric infrastructure and access to local media are also shown to reduce transaction costs, but their effects are less consistent across models.

Our study has limitations. The first limitation is that we do not know for certain whether a radial model, with Iganga as the central market, accurately reflects the operating environment. Additionally, if transaction costs are not stationary as the model assumes; the neutral band where it is not profitable to trade will change. We need actual transaction costs to determine this. However, the largest limitation with this study is data integrity. While much care was taken regarding missing observations, there isn't a formula to discern between data input errors and true price patterns. We try to account for this by looking for robustness of results but it is not without risk.

This study builds on prior work and provides policy makers with the current state of market integration in Uganda. With this information they will be able to focus solutions on the markets that are not cointegrated. Further work needs to be done to quantify the effects of infrastructure and telecommunications in a multivariate threshold cointegration framework so that policymakers can make prudent investment decisions. To be able to conduct that research, historical data is needed. Time series data including prices and some measure of transaction costs, infrastructure data related to roads, rail and vessels, and how market participants use telecommunications, will be important. This is an area that governments can address, and when compared to building underutilized infrastructure, it can be done relatively inexpensively.

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