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SPATIAL INTEGRATION OF MAIZE MARKETS IN POST-LIBERALIZED UGANDA

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ABSTRACT

Using weekly price data for two sub-periods, this paper analyzes how Ugandan maize market performed in the years following agricultural market liberalization in the early 1990's. For each time period, the extent of integration, causality among spatial locations, and relative importance of spatial locations in price formation are examined. The extent of integration, defined as a set of markets that shares common long-run price information, and the causal relationships among markets have been tested within Johansen's cointegration framework. The relative importance of each market locations is examined by estimating the common trend coefficients with a dynamic vector moving average model. Results indicate that, while there has been an overall improvement in spatial price responsiveness, the northern districts, which have been in a state of insurgency since 1986, continue to lack integration with major consumption markets in the central region. Causality test results show that compared to the 1993-1994-time period, representing the early years of liberalization, interdependence among markets has increased. Estimates of the common integrating trend suggest that public policies, such as price stabilization, can have desired impacts by targeting a small number of locations. These results are consistent with recently conducted household and market surveys in the country.

JEL Classifications: C32, O38, P11
Key words: Uganda, market integration, causality, common trend, and multivariate cointegration.

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SPATIAL INTEGRATION OF MAIZE MARKETS IN POST-LIBERALIZED UGANDA

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1. INTRODUCTION

Over the past two decades, many formerly centrally planned economies in Sub-Saharan Africa embarked on structural adjustment programs with an objective to promote market-based development. The expectation was that reduced government intervention would quickly pave the way for well-functioning markets to emerge, providing better price and production incentives for the farmers. Two decades of experience, however, have been unequivocally mixed. Instead of boosting production, there are empirical studies to show that rapid liberalization policies resulted in output reduction in many developing and transition economies (Kherallah, et. al. 2002; Eicher 1999; Seppala 1997; Chilowa 1998; Seshamani 1998; Brooks 1995; and de Alcantara 1993) [2]. One possible explanation for this unanticipated outcome, particularly in the context of transition economies, is the fact that the emergence of healthy systems of market exchange takes time, as traders need to learn arbitrage skills and build market relationships (Blanchard 1997, McMillan 1995).

The Republic of Uganda is such an economy. While the country is widely praised for successful economic reforms and transition to market economies, very little is known about how the agricultural markets, especially markets for staple food, performed in the

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[2] Blanchard and Kremer (1997) and Ronald and Verdier (1999) provide a theoretical explanation of declines in output when agents are required to develop new market relationship. Stiglitz (2002, p. 143) emphasizes the same point in the context of Russia where GDP fell for several consecutive years following the economic/market reforms.

years following reforms[3]. This paper attempts to fill this knowledge gap by analyzing how the extent and nature of maize market integration has changed since liberalization. In the early 1990s, when parastatals were being dismantled, some of the key elements of market failure—such as inadequate infrastructure, insufficient flow of price information, and regional/ethnic conflicts—were common in Ugandan agricultural markets. Localized supply shortages and price volatility, resulting from inadequate infrastructure and information asymmetry, were frequent challenge to the policy makers. The Famine Early Warning System Network (FEWS Net), established in the early 1990s, was a direct policy response to such market phenomenon. Available information also suggests that competition in the agricultural market was very limited. For example, two recent surveys conducted by the International Food Policy Research Institute (IFPRI) between 1999 and 2002 show that the majority of agricultural input and output traders started their business operation after 1993 and that the business network for long distance trade continue to be very limited[4].

Using weekly price data for two time periods, 1st week of 1993 to 40th week 94 and 40th week of 1999 to 30th week of 2001, this study examines the changes in: i) the extent of maize market integration, ii) the causal relationship across spatial markets, and iii) the relative significance of the market locations by estimating common trend coefficients. Empirical methodologies adopted to carry out these analyses are: Gonjalez-Rivera (2001) to examine extent of integration; Masconi and Giannini (1992) and Hall and Milne (1994)

[3] To the best of our knowledge, the only study that attempted to address this issue in Uganda is Larson and Deininger (2001). However, the main focus of this study is on the determinants of market participation and is based on cross section data.

[4] Sixty eight percent of output traders and 78% of the input traders started their trading business after 1993. Further details about changes in the level of competition, access to credit, and the business networks are provided in Section 4.

to test causality; and Gonzalo and Granger (1995) to estimate the common trend. The rest of the paper is organized as follows. The next section provides a formal description of the methodology, which is followed by descriptions of data and their time series properties. Details of the estimation procedures are provided in section 4. Section 5 presents the results along with some discussion on their potential implications. The paper concludes with a summary of the analysis and some concluding remarks.

2. METHODOLOGICAL FRAMEWORK

CHARACTERIZATION OF INTEGRATED MARKETS

Consider a market of a homogeneous commodity that is traded in n spatially separated locations with a corresponding price vector of $\{P_{1t}, P_{2t}, ...P_{nt}\}$. If trade exists among all locations, then these locations are said to be integrated if[5]:

i) $\{P_{1t}, P_{2t}, ...P_{nt}\}$ can be decomposed as $P_{it} = a_i f_t + \widetilde{P}_{it}$, $i = 1......n$, where f_t is the integrating vector that characterizes the permanent (long run) component and $\widetilde{P}_{it}$ is the transitory (short run) component for each location.

ii) for all i, $a_i \neq 0$, and

iii) $P_i's$ are co-integrated with exactly $n-1$ co-integrating vectors.

Conditions (i) and (ii) are standard in common trend analysis, but (iii) is a stricter condition, which ensures that there is *one and only one* common factor in a set of non-stationary price variables[6]. In an application to the Brazilian rice market, Gonzalez-Rivera and Helfand (2001) argue that before the search for a common trend can begin, researchers

[5] Similar characterization of market integration has also be used by Goodwin (1992), Silvapulle and Jayasuria (1994), Benson et. al. 1994, and Asche et. al. 1999. However, none of these studies attempted estimating associated common trend and persistence profile.

[6] It follows from the fact that there is a complete duality between VAR representation, used in analyzing co-integrating relations, and Vector Moving Average (VMA) representation that analyzes structure of common trend (Johansen 1991 and Juselius 1994).

need to check for trade flow reversal, which is also often cited as one of the weaknesses of using co-integration techniques in market integration analysis (Barrett and Li 2002). However, time series data on trade flow are not available in Uganda, or any other developing countries, at regional level. If such data were available, as Baulch (1997) points out, testing for efficiency of arbitrage would have reduced to a series of repetitive arithmetic calculations. Furthermore, although not precise, trade flow information is actually contained in price data. For example, if trade is bi-directional, and if traders are assumed to be profit maximizers, a trade flow reversal between two markets should be reflected through a reversal in price trends, at least in the long run. Therefore, our approach to determining trade flow has been to examine the plots of prices for all districts. Formal descriptions of three tasks, performed under this characterization of market integration, are provided below.

DETERMINATION OF $n-1$ CO-INTEGRATING VECTORS

The search for exactly $n-1$ cointegrating vectors in conducted in Johansen (1988) and Johansen and Juselius (1990) multivariate cointegration framework. Formally, let $P_t = \{P_{1t}, P_{2t}, ...P_{nt}\}$ be a $n \times 1$ non-stationary vector of prices where P_{it} is the log price of a homogeneous commodity at time t in market i. According to Granger representation theorem, the vector P_t has a vector autoregressive error correction representation

$$\Delta P_t = \Pi P_{t-1} + \sum_{i=1}^{k+1} \Gamma_i \Delta P_{t-i} + \mu + \delta t + \xi_t \qquad (t = 1, \cdots, T) \tag{1}$$

here Π and Γ are $n \times n$ matrices of coefficients; $\Delta = (I - L)$ and L is the lag operator; k is lag length; μ and δ are vectors of constants and trend coefficients respectively. If P_t is a vector of $I(1)$ variables, the left hand side and first $k-1$ terms on the right hand side of (2) are stationary or $I(0)$, and the 1st term on the right is a linear combination of $I(1)$ variables which, given the assumption on error term, must also be $I(0)$, i.e., $\Pi P_{t-1} \sim I(0)$. The hypothesis of cointegration is formulated as a reduced rank of Π and written as $\mathrm{H}(r)$: $\Pi = \alpha\beta'$, where r is the rank of Π that determines how many linear combinations of P_t are stationary, and α and β are $n \times r$ matrices of full rank. There are two methods of testing for reduced rank of Π, the maximum eigenvalue test, known as $\lambda_{\max}$ test, and trace test.

TESTING CAUSAL RELATIONSHIP

The existence of cointegration among a set of variables implies Granger causality, which, under certain restrictions, can be tested within Johansen's cointegration framework by standard Wald tests (Masconi and Giannini 1992; Hall and Milne 1994)[7]. The underlying principle is that if the α -matrix has a complete column of zeros, then no cointegrating vector should appear in a particular block, indicating no causal relationship. For a pair-wise causal relationship, this can seen by re-writing (1) in the following equivalent form[8]:

$$\begin{bmatrix} \Delta P_{1t} \\ \Delta P_{2t} \end{bmatrix} = \begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix} + \sum_{i=1}^{k-1} \begin{bmatrix} \Gamma_{i,11} & \Gamma_{i,12} \\ \Gamma_{i,21} & \Gamma_{i,22} \end{bmatrix} \begin{bmatrix} \Delta P_{1t-i} \\ \Delta P_{2t-i} \end{bmatrix} + \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix} \begin{bmatrix} \beta_1 & \beta_2 \end{bmatrix} \begin{bmatrix} P_{1t-k} \\ P_{2t-k} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix} \quad (2)$$

[7] The term causality refers to a variant of Granger causality, i.e., X Granger causes Y if a change in X predates a change in Y.

[8] Note that when there is exactly $n-1$ cointegrating vectors, it follows that all prices are pair-wise integrated (Stock and Watson 1987). In other words, if all prices are pair-wise cointegrated, there will be exactly n-1 cointegrating vectors with all prices sharing the same stochastic trend. A potential problem, however, is that the conclusions might differ depending on which pair is chosen, as all but $n-1$ pairs (out of possible $n(n-1)/2$ pairs) are redundant.

Where number subscripts denote markets and other notations are same as in equation 1. There are three possible cases of causality testing: ii) $\alpha_1 = 0,\ \ \alpha_2 \neq 0$; ii) $\alpha_1 \neq 0,\ \ \alpha_2 = 0$; and iii) $\alpha_1 \neq 0,\ \ \alpha_2 \neq 0,$ where the first two cases imply unidirectional causality and the third case suggest feedback between P_{1t} and P_{2t}. To see how causality implications are drawn, suppose that $\alpha_1 = 0$. This implies that the error correction term, i.e., the third term on the RHS, is eliminated and the long run solution to P_{1t} will be unaffected by the deviations from the equilibrium path defined by the cointegrating vector. Similarly, P_{1t} will not cause P_{2t} if $\alpha_2 = 0$.

ESTIMATING THE COMMON FACTOR f_t

To demonstrate how f_t is derived from (1), suppose P_t can be decomposed as,

$$P_t = A_1 f_t + \widetilde{P}_t \tag{3}$$

where A_1 is a $n \times (n-r)$ vector of loading coefficients, f_t is a $(n-r) \times 1$ vector of common unit root factors, and $\widetilde{P}_t$ is a $n \times 1$ vector of stationary transitory component. The standard factor analysis with cross section data usually relies on estimating the loading matrix A_1 in (2). Gonzalo and Granger (1995) demonstrate that, if there exists a linear combination of P_t (note that this is a critical condition for co-integration to exist), such that $f_t = B_1 P_t$, then f_t can be estimated from (1) as follows. By substituting $f_t = B_1 P_t$ into (2), the transitory component may be expressed as $\widetilde{P}_t = (I - A_1 B_1) P_t = A_2 Z_t$, where $Z_t = \beta' P_t$ is the error correction term. Relating this expression with (1), and by the principles of orthogonalization of matrices, it is clear that the only linear combination of P_t that can guarantee no long run impact of the transitory component $\widetilde{P}_t$ on P_t is,

$$f_{1t} = \alpha'_{\perp} P_t \tag{4}$$

The orthogonal condition $\alpha' \perp \alpha = 0$ ensures that the error correction term $Z_t = \beta' P_t$ is cancelled out so that there is no effect of transitory component on the long run forecast of P_t. The estimates of $\alpha'_{\perp}$, derived from the Vector Autoregressive Moving Average (VCM), provides additional information about the relative importance of each of the markets in long run price formation.

STRENGTHS AND WEAKNESSES OF THE METHODOLOGY

Despite remarkable improvement and extensions over the past three decades, the methods of market integration analyses continue to have limitations in capturing the complex intricacies of the way markets works, particularly in the developing countries. Neither of the two commonly used methods, Parity Bound Model (PBM) and cointegration, is free from criticism. The cointegration method is criticized be unreliable if: i) the transaction costs are non-stationary (Barrett 1996; Barrett 2001; Barrett and Li 2002; Mcnew and Fackler 1997; Fackler and Goodwin 2002), and ii) there are reversals in trade flows across markets (Barrett and Li 2002; Baulch 1997 a, b; Fackler and Goodwin 2002; Park et. al. 2002). On the other hand, the PBMs, as well as other bivariate cointegration method,[9] are criticized for: i) approaching multivariate problem in a bivariate framework, which can potentially lead to gross misspecification and omitted variable bias (Gonzalez-

[9] Bivariate cointegration is essentially an adaptation of Ravallion's (1986) radial integration model, in which integration is tested with respect to a central location. Studies that have taken this approach include: Palaskas and Harris 1993; Alexander and Wyeth 1994; and Dercon 1995.

Riviera and Hafland 2001) and ii) not being able to study market integration in the absence of trade flow data (Barrett and Li 2002, p294). Furthermore, the bivariate nature the PBMs can have serious implications on inferences drawn about market integration. For example, suppose that the speeds of adjustment coefficients $\alpha_{i's}$ are significant for all market locations. This would imply that all locations are highly interdependent and each location would react to deviation from the equilibrium in the other locations, which are commonly observed in both developed and developing country markets[10].

The argument behind the first criticism of cointegration method is that if transactions cost is non-stationary, failure to find cointegration between two price series may be consistent with market integration (Barrett 1996). In other words, rejection of cointegration hypothesis may not necessarily mean lack of market integration; it can just be a reflection of transfer costs being non-stationary. The conclusions of available cointegration-based studies, however, go largely against this contention. Instead of finding lack of integration, most of the available cointegration-based studies have concluded in favor of market integration. And these conclusions conform for countries with very different level of developments, including Brazil (Gonzalez-Rivera and Hafland 2001), Indonesia (Alexander and Wyeth 1994), Ethiopia (Dercon 1995), the Philippines (Silvapulle and Jayasuria 1994), and Bangladesh (Dawson and Dey 2002). There are few cases, such as Alexander and Wyeth 1994, where one or two locations in a given set of markets lack integration, but it is hard to attribute them entirely to the non-stationarity of transaction costs. On the other hand, Fafchamps and Gavian (1996) demonstrate that when

[10] Gonzalez-Rivera and Hafland (2001) offers a number of other examples supporting multivariate market integration analyses. See Ache et. al. (1998) and Dawson and Dey (2002) for significance of such interdependence.

markets do lack integration, both PBM and cointegration methods may lead to the same conclusions.

The second set of criticisms against cointegration method is that it cannot distinguish various arbitrage conditions, such as autarky, efficient arbitrage, and arbitrage failure. Given our characterization, efficient arbitrage and arbitrage failures are reflected through integration and non-integration of markets. The autarkic conditions, however, are not distinguishable. Consider the following simple hypothetical examples. Suppose that two surplus markets, say A and B, do not engage in trade because the price differential between them is less than transfer costs, but both markets supply to a major urban location, say C, with which price differentials are large enough to cover the transfer costs. Now, if A and B are integrated to C, prices in these markets are likely to co-move over time, as price shocks in C will be transmitted to the other two markets. In this situation, the cointegration results might indicate that all three markets are integrated, although there is no trade flow between A and B. The failure to make this distinction is a limitation of the method. But for a small country such as Uganda, and the district markets that we have considered, this is hardly a problem, as neither local experts nor available market survey data suggests autarky across districts.

3. DATA AND THEIR TIME SERIES PROPERTIES

The weekly price data used for this study are taken from two sources, namely Famine Early Warning System Network (FEWS-net) and the *Foodnet* of the International Institute of Tropical Agriculture (IITA). The FEWS-net was established in the early 90's with an objective to strengthen the capacities of African nations in responding to food security threats, such as localized supply shortages and crop failure, through timely analysis of food price variability, remotely sensed agro-climatic data, and other vulnerability information. The network started compiling weekly maize price data in eight Ugandan districts from the first week of January 1993 and gradually increased its coverage to 23 districts by 1996. This study uses first 91 weeks of data for the following districts: Kampala*,* Jinja*,* Masaka, Gulu, Arua, Mbarara*,* Hoima*, and* Mbale. This selection is guided by two factors: i) price series for the other districts, particularly after 39th week of 1994, are unusable due to large gaps and missing values[11]; and ii) in terms of the length of time series, taking the first 91 weeks of FEWS-net data matches with the length of *Foodnet* data for the selected districts, which allows a comparative analysis of how maize market integration has changed since early years of liberalization.

From January of 1999, when Foodnet was being developed as a full-fledged provider of market information services for food crops, the FEWS-net discontinued compiling price data. The *Foodnet,* however, started data collection from September 1999 and, as figure 1 shows, data collection and radio broadcasting did not begin simultaneously in all districts; most of the districts were brought under radio broadcasting in 2000 and

[11] The missing values problem becomes severe from the 92nd week. For instance, starting from 92nd week, price data are missing for all districts for a period of thirteen weeks.

2001. Altogether, *Foodnet* now collects and radio broadcasts weekly price data for 18 major food crops in 16 districts of Uganda. While prices for all other districts are district averages, prices in Kampala are collected from two major food markets in the city, namely *Kisenyi* and *Owino*. Three types of weekly prices—wholesale, retail, and off lorry—are available from *Foodnet*. This study uses district level wholesale price of maize in selected districts, shown in figure 1. Some basic analysis regarding time series properties of both data sets are discussed below.

Some basic analyses are carried to explore the time series properties of the data that include: i) pair-wise plots for each of the markets with Kampala, and ii) stationarity tests (unit root tests) on all variables. First, since Kampala is the dominant consumption market, we check the price relationships between Kampala and other markets. Although plots are drawn for all pairs of prices, only Kampala-Gulu and Kampala-Arua are shown in figure 2 and figure 3. Notice that, while there are some short run fluctuations, all plots except Kampala-Arua show a common pattern i.e., prices of other markets are less than Kampala prices and exhibit a clear co-movement over time. The Kampala-Arua plots show different trends in the two different periods. For much of the 2000 and 2001, Arua price was higher than Kampala price, although it was lower during 1993-1994-time period. Based on our field experiences, there can be two possible explanations for this reversal in Kampala-Arua price trend. The district is either not part of the greater Ugandan maize market because of insecurity problems or, since it is a border district, it engages in trade with neighboring countries. However, local experts conducting field works in the regions believe that the trading with the neighboring countries is a more plausible explanation[12].

One of the essential first steps in co-integration analysis is to test for the stationarity (or order of integration) properties of the time series. The tests of stationarity are important because there is a one-to-one relationship between the number of stationary variable and the number of co-integrating relationships (Hansen and Juselius 1995). In particular, if x numbers of stationary variables are included into the co-integration space, the number of co-integrating vectors will also increase by x. Therefore, given our definition of market integration (i.e., finding exactly *n-1* co-integrating vectors), inclusion of stationary variables can potentially change the conclusions about the extent of integration.

Augmented Dicky-Fuller method has been used to test for the order of integration and optimum lag length is determined based on Akaike Information Criterion (AIC)[13]. The results, presented in Table 1, indicate that while all prices series in *Foodnet* database are $I(1)$ (i.e., difference stationary), Masaka and Mbarara price series in FEWS database are $I(0)$ (i.e., stationary in levels). This implies that those two district markets did not share the common trend with dominant central markets, such as Kampala and Jinja, in the early 1990's. Therefore these markets are excluded from cointegration rank and common trend analyses, as inclusion of them would increase the number cointegrating vectors.

[12] A number of seminar participants in Kampala, who have extensive field experiences, told me that traders in the northern districts commonly use U.S dollars for commodity trading with traders from Democratic Republic of Congo and Sudan.
[13] Depending on their significances, trends and constants terms were also included in unit root testing.

Figure 1—Sampled districts, data sources, and length of *Foodnet* radio broadcasting

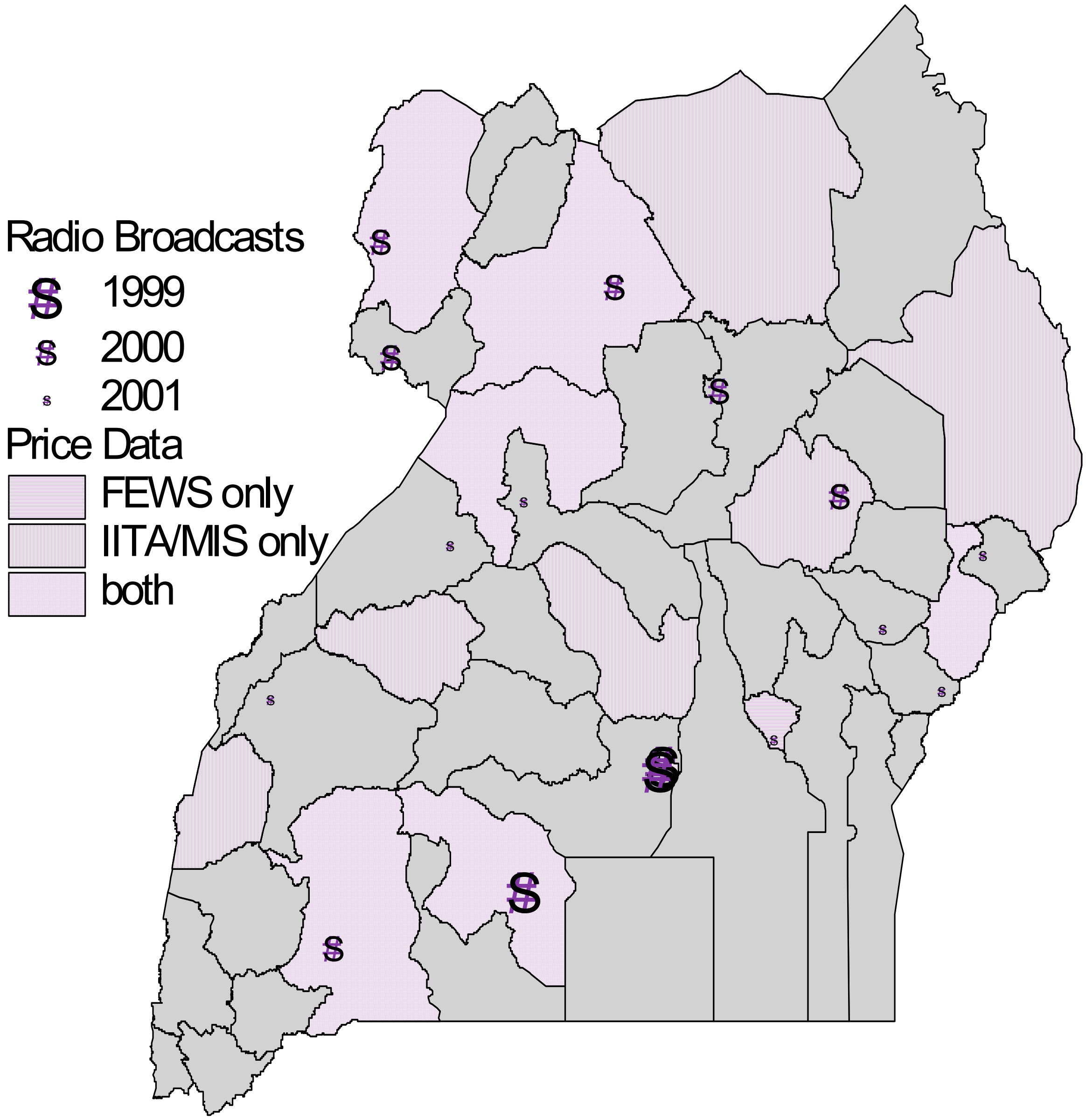

Figure 2—Comparison of Kampala-Gulu prices

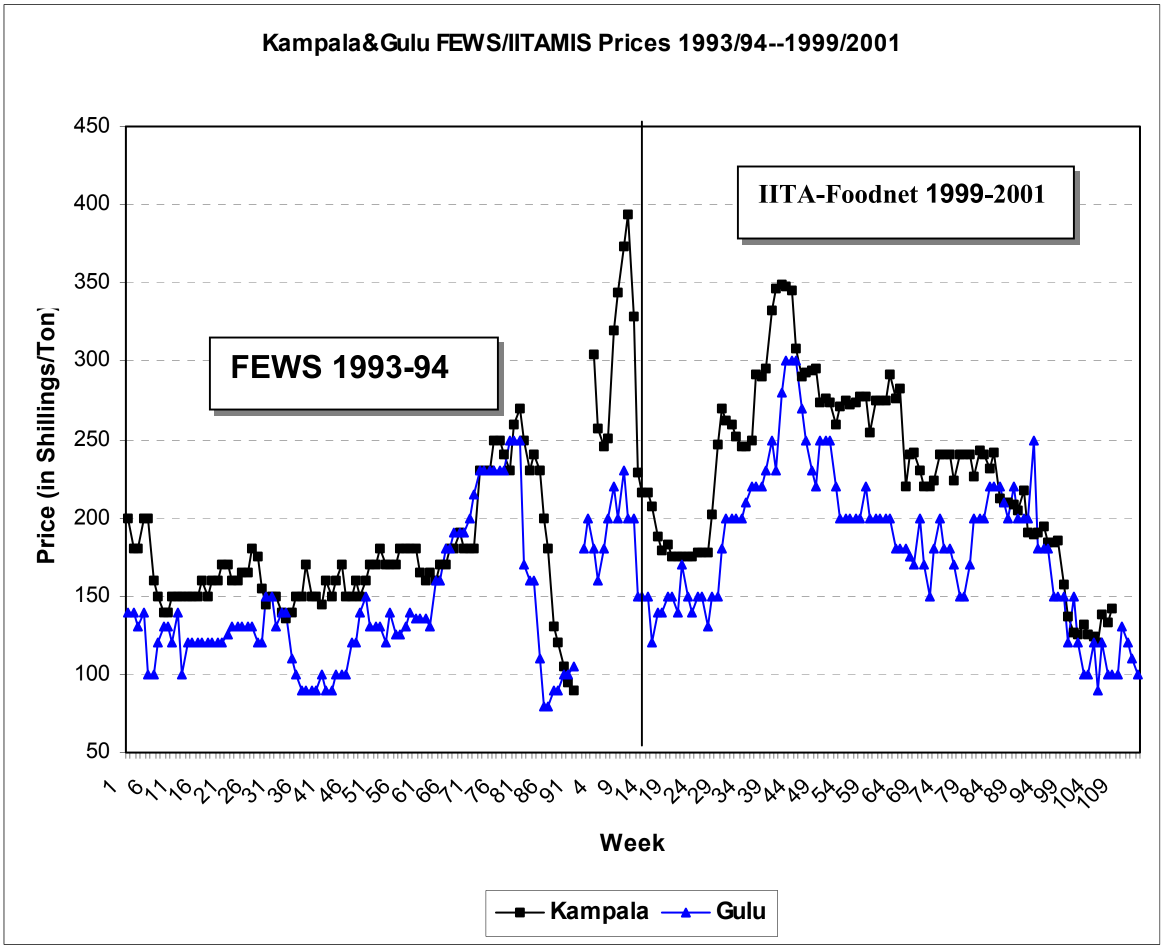

Figure 3—Comparison of Kampala-Arua prices

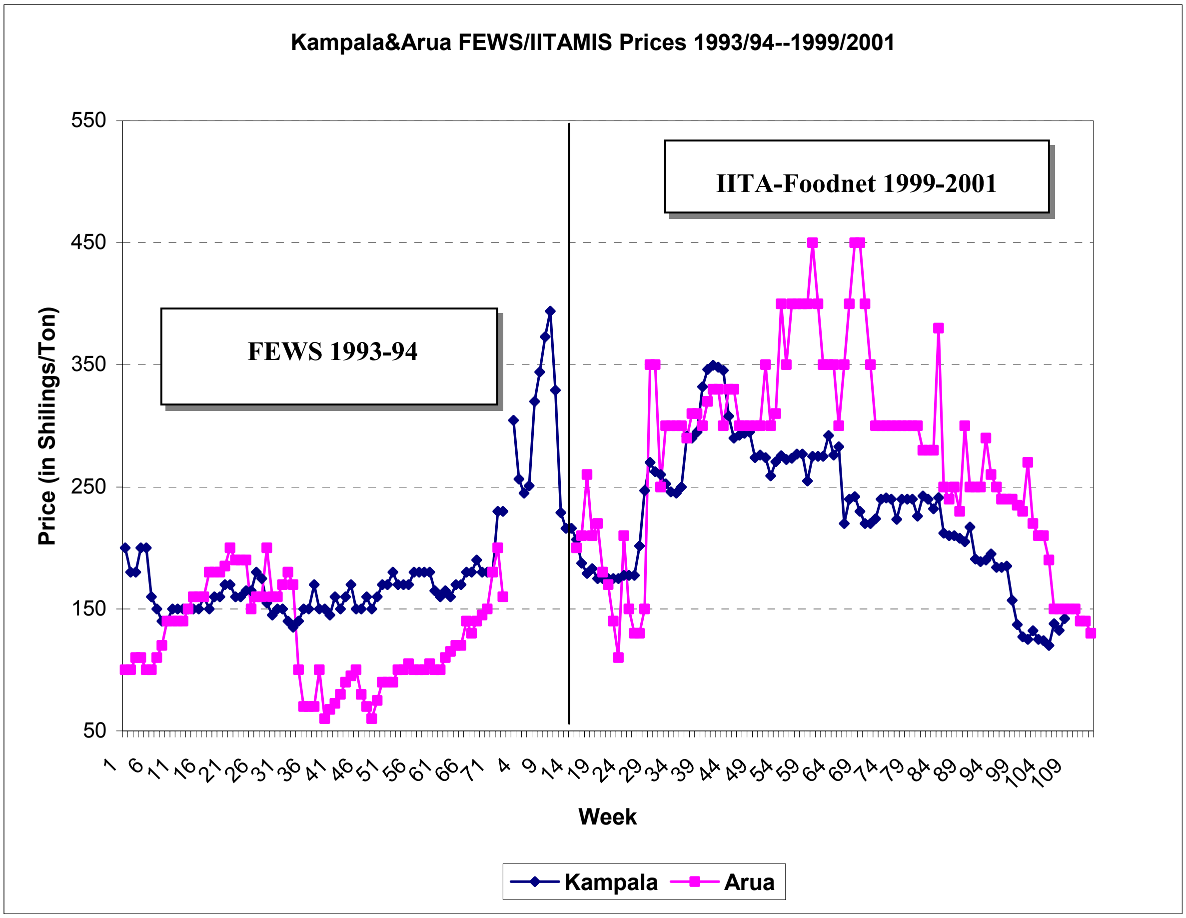

Table 1—Augmented Dicky-Fuller unit root tests on selected variables

Time Series	FEWS Data		Foodnet Data	
	Levels	First Difference	Levels	First difference
Kampala	-0.25	-8.18	-1.31	-8.87
Gulu	-2.43	9.66	-2.4	-3.21
Mbale	-2.03	-5.01	-1.35	-11.78
Mbarara	-3.51	-8.09	-2.05	-9.75
Hoima	-1.62	-4.34	--	--
Jinja	-1.13	-9.22	-1.45	-5.21
Masaka	-5.13	-14.57	-0.5	-8.2
Iganga	--	--	-1.63	-4.0
Lira	--	--	-0.39	-8.7

Notes: All variables are in natural logarithm. Augmented Dicky-Fuller (ADF) test results are presented. It tests $H_0 : X_i \sim I(1)$ against $H_0 : X_i \sim I(0).$ Using McKinnon (1991), the relevant critical value at 5% level of significance is -3.07.

4. EMPIRICAL RESULTS

GENERAL NOTE ON ESTIMATION

Several diagnostic tests are critical in implementing the methodology outlined in Section 3. The most important diagnostic involves determination of cointegration rank (i.e., rank of Π), which depends on what deterministic components (constant, time trend, etc.) enter into the cointegration space as well as the lag length in the VAR (Johansen 1992, Johansen and Juselius 1992, and Boswijk and Francis 1992). This paper supplements Johansen's (1992) Pantula method with other tests for determining cointegration rank; and Doornik and Hansen's (1994) modified version of the Shenton-Bowman test for residual normality.

Three different models have been considered in determining cointegration rank and the appropriate deterministic components. The first model restricts all deterministic components to a constant in the cointegration relation; the second model allows a constant plus a deterministic trend in level; and the third model accounts for a constant in the cointegrating relation, a trend in level, and a trend in cointegrating relations. The ordering of the models is done from the most to the least restrictive. Johansen's (1992) model selection methodology states that, "starting from the hypothesis of zero cointegrating vector and most restrictive model, model selection testing should continue until the null is accepted". To demonstrate how it works, read Table 2 row-by-row from left to right. Note that for r=0 through r=2, the null is clearly rejected for all three models. The first time the null hypothesis is accepted at 5% level of significance is when r=3 under the first model. Thus, based upon these results, we conclude that the model that restricts all deterministic components into a constant is the appropriate model, and there are three cointegrating vectors[14].

As described earlier, the extent of market integration is analyzed through a sequential search for exactly *n-1* cointegrating vectors, which is conducted as follows. Starting with Kampala and Jinja, two major district markets in Uganda, cointegrating relationships are estimated with two lags and seasonal dummies. For each set of cointegration results, residuals were saved and tested for normality. If residuals were found to be normal, another district was added and the previous procedure was repeated[15]. On the other hand, if residuals were found to be non-normal, the lag length was increased and tested for normality before adding another district. Table 3 presents the eigenvalues, cointegrating vectors, and the normality test results for the final set of market.

Table 2—Co-integration rank test and selection of deterministic components (FEWS Weekly data, 1993-94, k=4)

Null Hypotheses	Model 1 $\lambda_{Trace}\ stat$	Model 1 $\lambda_{Trace}(0.95)$	Model 2 $\lambda_{Trace}\ stat$	Model 2 $\lambda_{Trace}(0.95)$	Model 3 $\lambda_{Trace}\ stat$	Model 3 $\lambda_{Trace}(0.95)$
$r=o$	113.19→	53.12	111.99	47.21	130.07	62.99
$r \leq 1$	65.11	34.91	63.93	29.68	77.48	42.44
$r \leq 2$	27.45	19.96	26.75	15.41	29.42	25.32
$r \leq 3$	3.43	9.24**	3.16	3.76	3.21	12.25

95% Critical values are taken from Osterwald-Lenum (1992).
** Indicates that the null hypothesis of number of co-integrating vectors indicated by first column cannot be rejected for that particular model.

[14] Note that although this procedure is followed for each set of regressions in analyzing the extent of market integration, for the sake of brevity, detailed results are not presented in the paper. They are available from the author upon request.

[15] Sequential addition of district markets was done on the basis of distance between Kampala and a given district headquarters, in the order of nearest to the furthest (see Table 9).

Table 3—Eigenvalues, cointegration vectors, and residual misspecification tests

Eigenvalues	Cointegration vectors							
	Kampala	Jinja	Hoima	Mbale	Iganga	Masaka	Mbarara	Lira
FEWS DATA (1993-94, k=4)								
0.54	1.000	-1.379	-0.145	0.882	--	--	--	--
0.40	0.126	1.000	-0.905	0.196	--	--	--	--
0.24	-1.424	-2.08	1.000	-1.424	--	--	--	--
0.14	-3.025	-2.215	2.521	1.000	--	--	--	--
Tests for residual normality								
	1.55	0.099	5.45	4.12	--	--	--	--
IITA-FOODNET DATA (1999-2001, k=3)								
0.7594	1.00	-0.60	--	-0.34	0.32	0.04	-0.26	-0.29
0.4989	0.03	1.00	--	-0.70	-0.14	0.33	-0.20	-0.52
0.4006	0.14	-0.20	--	1.00	-0.60	-0.04	0.00	-0.19
0.2587	-0.24	0.34	--	-1.67	1.00	0.07	-0.01	0.32
0.1732	-0.19	-0.08	--	0.09	-0.55	1.00	0.07	-0.56
0.1149	-0.19	0.27	--	0.41	3.36	-1.33	1.00	-4.73
0.0758	0.04	-0.06	--	-0.09	-0.71	0.28	-0.21	1.00
Tests for residual normality								
	7.765	7.611	--	4.403	1.182	7.776	0.036	0.103

Normality tests are conducted using Doornik and Hansen's (1995) modified version of Shanton-Bowman (1997) test of normality. The test statistics follow χ^2 distribution with two degrees of freedom.

EXTENT OF INTEGRATION

As indicated earlier, the extent of integration is determined through a sequential search for $n-1$ cointegrating vectors. The Johansen's λ_{Trace} test results for this sequential search in FEWS price data sets are presented in Table 4. For each set of markets, the null hypothesis of $r = n-1$ is tested against the alternative that $r = n-2$, where r is the cointegrating vector and n is the number of markets. Notice that the hypothesis of *n-2* (i.e., r=1 for the first set of markets, and r=2 for the second set) cointegrating vectors is clearly rejected for the first two sets of markets. However, when Gulu is added, we fail to reject the null hypothesis of *n-2* cointegrating vectors at 5% level of significance. The same holds true for Arua at the 10% level of significance. Therefore, we conclude that maize markets in these two districts, and in Masaka and Mbrara, which are tested stationary in levels, did not share the common trend with other major markets in the country during 1993 –1994.

The same sequential methodology was applied to 1999-2001 *Foodne*t data. These set of analysis drops Hoima, for which price data are not available in the *Foodnet* database. Although price series were available for 16 districts, carrying out the analyses with all districts turned out to be computationally unmanageable, particularly due to low degrees of freedom resulting from inclusion of seasonal dummies. Therefore, only eight districts—Kampala Jinja, Masaka, Iganga, Mbarara, Mbale, Lira, and Gulu—were included into the analysis. The sequential trace test results (Table 5) suggest that the extent of maize market integration in Uganda has substantially improved in recent years. All district markets, except Gulu and Arua, are found to have shared a common trend during 1999-2001-time period. Furthermore, Masaka and Mbarara, which were tested stationary in levels during 1993-1994-time period, are now significantly integrated with the other markets.

Table 4—Johansen's likelihood ratio test for the number of co-integrating vectors

$H_0 : r = n-1 \, against \; H_a : r < n-1$

Markets	r	Trace stats	Critical Values	
			Trace (0.95)	Trace (0.90)
FEWS WEEKLY DATA (1993-94; k=4)				
Kampala and Jinja	0	34.09	19.96	17.79
	1	2.53	9.24	7.50
Kampala + Jinja + **Hoima**	1	23.47	19.96	17.79
	2	2.68	9.24	7.50
Kampala + Jinja + Hoima **+ Mbale**	2	27.45	19.96	17.79
	3	3.43	9.24	7.50
Kampala + Jinja + Hoima + Mbale **+ Gulu**	3	15.48	19.96	17.79
	4	2.89	9.24	7.50
Kampala + Jinja + Hoima + Mbale + **Arua**	3	18.27	19.96	17.79
	4	3.97	9.24	7.50

Table 5—Johansen's likelihood ratio test for the number of co- integrating vectors

$$H_0 : r = n - 1 \, against \;\, H_a : r < n - 1$$

Markets	r	Trace stats	Critical Values [a]	
			Trace (0.95)	Trace (0.90)
IITA FOODNET DATA (1999-2001)				
Kampala + Jinja	0	33.24	19.96	17.79
	1	6.06	9.24	7.50
Kampala + Jinja+ **Iganga**	1	38.07	19.96	17.79
	2	12.21	9.24	7.50
Kampala + Jinja+ Iganga+ **Masaka**	2	40.52	25.32	22.76
	3	11.07	12.25	10.49
Kampala + Jinja+ Iganga+ Masaka + **Mbale**	3	37.06	25.32	22.76
	4	11.21	12.25	10.49
Kampala + Jinja+ Iganga+ Masaka + Mbale + **Mbarara**	4	21.91	19.96	17.79
	5	6.47	9.24	7.50
Kampala + Jinja+ Iganga+ Masaka + Mbale + Mbarara + **Lira**	5	25.46	25.32	22.76
	6	7.66	12.25	10.49
Kampala + Jinja + Masaka+ Iganga + Mbarara + Mbale + Lira **+ Gulu**	7	11.83	19.96	17.79
	8	3.34	9.24	7.50
Kampala + Jinja + Masaka + Iganga + Mbarara + Mbale + **Gulu** **(**Lira dropped**)**	7	12.69	19.96	17.79
	8	3.77	9.24	7.50

[a] Critical values, taken from Osterwald-Lenum (1992), changes depending on which of the three models is selected.

There are two general conclusions that emerge from the above results: i) compared to early 90's, the extent of Ugandan maize market integration has improved in recent years, and ii) northern districts continue to exhibit non-integration to the dominant markets in the central region. These results are easily interpreted in the context of the political realities and the history of market liberalization in the country. In the early 1990's, the country was just coming out of the parastatal regime, and the necessary institutions that ensure healthy commodity exchange were still in their infancies. As stated earlier, thinness in agricultural commodity markets during early 1990's is evident in recent surveys of agricultural markets, which show that majority of input and output traders in the country are first generation traders, and started their business operation after 1993. Specifically, 68 percent of agricultural output traders and 78 percent of input traders started their trading operation after 1993 - 1994. Some preliminary analyses of these survey data also suggest that the long distance commodity trading is very limited in the country. As Table 6 shows, on the average, traders operate within a radius of 73 square kilometers, and only about 21 percent of the transactions involved credit.

The lack of integration between central and northern districts reflects the political realities of the country. The northern districts, such as *Gulu* and *Arua*, have been in a state of insurgency since the Museveni government came to power in 1986, which has been a major hindrance to the development of market/trading linkages with the consumption markets in the central districts. Furthermore, as we have already alluded in Section 3, although there are legal restrictions, traders in these districts engage in trade with the neighboring countries. Therefore, whenever there is demand from the neighboring countries, prices in the regions go up, sometimes substantially higher than prices in the main consumption markets. If markets were integrated across national borders, such price differential would not have existed, as traders from the other regions would quickly respond to the price increase.

The poverty implications of these results are also consistent with available recent studies recent studies on poverty dynamics in Uganda and elsewhere in Sub-Saharan Africa. For instance, using panel surveys, conducted by the Uganda Bureau Statistics, Appleton (1998) demonstrated that while absolute poverty in the country declined from 56% in 1992 to 46% in 1996, the overall poverty in the northern districts had actually increased during the same time period. Christiansen et al (2002), who reviewed poverty trends in African countries during the 90's, also found similar connection. They concluded, "Market connectedness is the key for the poor to benefit from new opportunities generated by economic growth. Some population groups and regions, by virtue of their sheer remoteness, have been left behind when growth picked up". Given that data are very aggregated, this study cannot argue about connectedness of remote markets, but certainly provides some evidence that highlights the linkage between markets and poverty.

Table 6—Selected indicators of Ugandan agricultural markets*

Regions and Districts	Years in the agricultural trading	Distance from trading premise to:		Number of competitors		% Of transactions on credit
		Purchase markets (Kms)	Sales markets (Kms)	At the start of the business	In 2000	
Central						
Kampala	5.12	199	68	58.50	108.6	33.75
Luwero	6.50	15	21	84.25	48.67	22.29
Masaka	5.27	35	46	36.95	54.73	27.92
Mpigi	6.69	34	19	30.27	40.07	17.80
Mukono	7.55	30	15	55.12	42.39	24.10
Av. Central Region	**6.22**	**74**	**35**	**54.73**	**68.54**	**24.30**
East						
Busia	3.00	360	12	7.00	50.00	45.00
Iganga	6.28	32	73	69.68	118.96	14.28
Jinja	9.00	101	100	90.50	192.88	15.25
Kamuli	6.79	27	32	14.83	25.63	20.80
Mbale	7.48	37	40	33.97	106.38	17.26
Pallisa	5.16	41	32	35.77	79.72	16.00
Tororo	5.61	35	16	46.47	90.44	13.67
Av. Eastern Region	**6.31**	**55**	**45**	**42.72**	**91.26**	**19.08**
North						
Apac	4.53		106	15.03	32.11	5.75
Arua	4.12	27	49	12.65	25.35	17.50
Lira	11.68	302	47	23.52	97.10	19.18
Gulu	6.65	99	93	8.65	12.30	13.00
Kitgum	2.82	85	44	19.37	21.00	20.00
Nebbi	4.50	30	25	36.54	80.52	24.80
Pader	.00	30	349	30.00	30.00	
Av. Northern Region	**5.95**	**50**	**84**	**17.42**	**42.28**	**17.06**
West						
Bushenyi	3.89	57	47	105.33	150.3	12.40
Hoima	3.40	41	143	113.70	36.10	
Kabale	8.22	117	53	23.94	22.33	29.33
Kabarole	4.11	135	73	13.78	21.00	30.00
Kasese	9.44	17	33	24.22	43.67	27.67
Masindi	2.57	33	109	26.23	32.04	18.14
Mbarara	6.80	108	106	11.30	15.80	26.00
Rukungiri	9.25	142	21	48.50	43.25	1.00
Av. Western Region	**5.72**	**80**	**77**	**43.85**	**40.53**	**19.50**
Av. West Nile	**4.40**	**103**	**32**	**30.10**	**65.63**	**22.71**

* Source: Author's calculation based on IFPRI Agricultural Output Traders survey, 2000-2002.
Note: The survey is based on a sample of 544 traders dealing in coffee, cotton, maize and cassava.

CAUSALITY TESTS

Causality test results are presented in Table 7. The causality tests on the FEWS database, presented in the top panel of the table, suggest that for all market pairs involving Kampala and Jinja, the hypothesis of $\alpha_2 = 0$ cannot be rejected at a conventional level of significance. This implies that the causality is unidirectional, with prices in the regional markets Granger causing the prices in these two large urban centers. However, both way causalities (or feedback) are found to exist between Mbale and Hoima, indicating interdependence between these two markets. In other words, price in one market reacts to any deviation of price in the other market from its equilibrium path.

Bi-directional causality is found to be more common in the Foodnet database. Out of eleven market pairs reported in Table 7, causal feedbacks are found to exist in five pairs (i.e., Kampala-Jinja, Kampala-Mbarara, Kampala-Lira, Jinja-Lira, and Jinja-Iganga), which is an indication of increased interconnectedness of regional markets during the 1999-2001-time period. These results also point to the limitations of bivariate market integration analyses, where a central location is assumed to be exogenous, i.e., to dominate the long run price movements. In our analyses, if Kampala were indeed such an exogenous location, then all other $\alpha_{i's}$ would have been statistically zero, which clearly is not the case. Moreover, even if Kampala was exogenous with all other $\alpha_{i's} = 0$, a bivariate analysis would be inappropriate unless an additional restriction—that is, each location adjusts to its disequilibrium with respect to the exogenous location—is satisfied (Gonzalez-Rivera and Hafland 2001). This analysis suggests that neither of these conditions is supported by the data.

Table 7—Bivariate causality tests

Market Pair	Null Hypotheses	Trace Stat[a]	Causality	
			α_1 =0	α_2 =0
FEWS DATA (1993-94)				
Kampala-Jinja	$r=0$	64.45	55.24*	0.69
	$r\leq 1$	3.09	(0.00)	(0.41)
Kampala-Hoima	$r=0$	19.50	8.22*	0.81
	$r\leq 1$	2.97	(0.00)	(0.37)
Kampala-Mbale	$r=0$	23.44	17.85*	0.83
	$r\leq 1$	3.74	(0.00)	(0.36)
Jinja-Hoima	$r=0$	18.13	10.43*	1.69
	$r\leq 1$	3.54	(0.00)	(0.19)
Jinja- Mbale	$r=0$	17.94	9.35*	0.25
	$r\leq 1$	3.11	(0.00)	(0.62)
Mbale-Hoima	$r=0$	20.03	10.04*	9.45*
	$r\leq 1$	1.64	(0.00)	(0.00)
FOODNET IITA DATA (1999-2001)				
Kampala-Jinja	$r=0$	19.71	3.80*	6.52*
	$r\leq 1$	6.31	(0.05)	(0.01)
Kampala-Iganga	$r=0$	34.28	9.65*	0.19
	$r\leq 1$	11.79	(0.00)	(0.66)
Kampala-Masaka	$r=0$	20.51	14.13*	0.62
	$r\leq 1$	3.11	(0.00)	(0.43)
Kampala-Mbale	$r=0$	27.30	8.68*	1.49
	$r\leq 1$	9.26	(0.00)	(0.22)
Kampala-Mbarara	$r=0$	28.50	4.84*	10.78*
	$r\leq 1$	2.17	(0.03)	(0.00)
Kampala-Lira	$r=0$	43.42	24.22*	7.45*
	$r\leq 1$	3.17	(0.00)	(0.01)
Jinja-Iganga	$r=0$	45.19	6.98*	5.67*
	$r\leq 1$	5.86	(0.01)	(0.02)
Jinja-Masaka	$r=0$	26.71	5.35*	0.16
	$r\leq 1$	10.62	(0.02)	(0.69)
Jinja-Mbarara	$r=0$	17.04	1.43	5.6*
	$r\leq 1$	4.00	(0.23)	(0.02)
Jinja-Mbale	$r=0$	38.14	15.27*	3.19
	$r\leq 1$	6.72	(0.00)	(0.07)
Jinja-Lira	$r=0$	62.45	8.14*	31.33*
	$r\leq 1$	6.10	(0.00)	(0.00)

[a] The null hypothesis of $r\leq 1$ has been significant for all market pairs at 95% confidence level.
* Significant at 95% confidence level
P-values in parenthesis

COMMON TREND COEFFICIENTS

Common factor coefficients are estimated using (4) and the results are reported in Table 8[16]. Since the same set of markets could not be analyzed for both time periods, these coefficients are not one-to-one comparable. However, the estimated coefficients appear to be very consistent with the consumption and production statistics of the country. With estimated coefficients of 0.77 and 0.617 for 1993-1994 and 1999-2001-time periods respectively, Kampala is found to be the leading location in long run price formation. The next most important location in price formation is Jinja, the district with second largest city in the country, for which estimated common factor coefficients are 0.52 for FEWS and 0.509 for Foodnet data set.

In order to check whether common factor coefficients are in conformity with the maize production statistics, we have reported total production, total acreage, and per capita maize production in Table 9. Mbale, which ranks first in terms of total production of maize among four markets in the FEWS database, has the third largest common factor coefficient. Similarly, in the Foodnet data, Iganga, top maize growing district in the country, has the third largest common factor coefficients. The estimates suggest that a relatively small number of market locations, mainly large consumption and production districts, dominate the long run price transmission. This implies that public policies, such price stabilization, can be targeted at small number of location and still be effective in influencing all locations that are integrated.

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[16] Note that, for each time period, the significance of the coefficients was tested using a Likelihood Ratio (LR) test. Based on these tests, Masaka was dropped, as the null hypothesis of its coefficient being statistically zero could not be rejected. The test statistics was 8.51, which is distributed as χ^2 with six degrees of freedom. The p-value associated with the test is 0.20.

Table 8—Comparison of estimated common trend coefficients

Markets	Common Trend Coefficients*	
	FEWS	Foodnet
Kampala	0.770	0.617
Lira	-	0.330
Mbale	0.330	0.033
Mbarara	-	0.401
Jinja	0.520	0.509
Iganga	-	0.403
Hoima	0.160	-

* These are absolute values of the estimated orthogonal complements of alpha. Lag length for FEWS and Foodnet are 4 and 3 respectively. Based on Johansen's (1992) model selection results, all deterministic terms were restricted to a constant for FEWS data; and a constant and a linear trend in cointegrating relations in Foodnet data.

Table 9—Production per 1000 population in selected districts of Uganda

Districts	Total Production (in 000 MT)	Total Acreage (in 000 hectares)	Distance from Kampala (km)[a]
Kampala	0	0	0
Jinja	11.34	8.4	73
Iganga	43.79	32.4	108
Masaka	6.46	4.78	127
Hoima	16.71	12.6	194
Mbale	30.57	22.63	217
Mbarara	18.88	13.97	267
Gulu	20.37	15.17	338
Lira	35.03	26.07	348
Arua	29.25	21.64	495

Source: Uganda Bureau of Statistics.
[a] It is the distance between Kampala city and the respective district head quarters.

5. CONCLUSIONS

Using weekly price data for two time periods, this paper has analyzed the spatial integration of Ugandan maize markets since the early 1990s. For each time period, changes in the extent of integration, causal relationship among market locations, and the relative importance of market locations in long run price formation have been examined. Three broad conclusions emerge from the study. First, compared to the early years of liberalization, represented by the 1993-1994-time period, the extent of integration in Ugandan maize markets appear to have improved in recent years. Market locations, such as Masaka and Mbarara, which did not share the common trend with the main consumption markets (Kampala and Jinja) in the early 1990's, were integrated by the 1999-2001-time period. These results provide empirical support to the hypothesis that it takes time for markets to emerge in transition economies.

Second, the study finds that the northern districts continue to lack integration with central markets. Neither of the two districts considered in this study are found to be integrated with the main consumption markets. The null hypotheses that these markets share a common stochastic trend with other locations are rejected at less than 5% level of significance. Given the current political situation in the northern part of the country, this result should not come as a surprise. The northern districts have been in a state of insurgency since the current government came to power in 1986, which might have hindered establishing trade relationship with other districts. In the context of market connectedness and poverty, this finding is consistent with studies on regional poverty in Uganda.

Third, the causality test results indicate that bi-directional causal relationships, or feedbacks, were more common during 1999-2001-time period, which further validates the conclusion of improved market integration in recent years. Furthermore, this result also reinforces the shortcomings of commonly used bivariate market integration models, where a central location is assumed to be exogenous, i.e., to dominate the long run price movements. In our analyses, if Kampala were indeed such an exogenous location, then the causal relationship would have been uni-directional, which clearly is not the case.

Finally, the estimates of the coefficients of common integrating factors suggest that the long run price formation is dictated by a relatively small number market location. During 1999-2001-time period, only four out of eight integrated market locations were found to dominate the long run price transmission. The significance and magnitude of the coefficients are consistent with demand and supply conditions in the country. For example, the largest coefficient is associated with Kampala, the largest consumption district, which is followed by Iganga and Lira, the largest and second largest maize producing districts in the country. This implies that the public policies, such as price stabilization, can have desired impacts by targeting a small number of market locations.

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