Livestock Market Integration and Price Discovery: Case of Mali

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Introduction

Economic importance of livestock in Mali

The Republic of Mali is a landlocked country located in the Western part of Africa. Mali is a low-income, agro-pastoral economy where agriculture accounts for 35.7% of the GDP, 80% of employment and the livestock sector alone contributes to around 15% of the GDP and 30% of the employment (FAO, 2005). The livestock sub-sector accounted on average for 11% of the GDP during the period from 1991-2002 and its contribution to export earnings were about 62.4 billions of FCFA in 2001 ranking third after the cotton and gold (Ministry of Livestock and Fisheries, 2004). Livestock and especially cattle play a great role in income generating activities of the Malian population. In fact the livestock and cotton are the important differentiating factors of income generation among households in Mali. Generally in rural household in Sub-Saharan Africa, holding cattle is considered as a sign of wealth because households can use livestock as collateral for loans and it generates revenues from animals and by-products sold.

Livestock marketing and market liberalization in Mali

FAO (2005) reports that since 1981 the government of Mali adopted the economic reforms comprising price and trade liberalization, reform regarding business regulations and the privatization of state-owned enterprises. Some of the economic reforms were at the heart of the creation of market news services which sought to encourage the competitive growth of the private sector by improving market transparency.

Historically, the Market Information System (MIS) was created in Mali in 1989 as a part of the Cereal Reform Program and in response to the Structural Adjustment reforms (Dembele, N. and J. Staatz, 2004). Vitale and Bessler (2006) noted that Mali has been an exception in the West Africa to take on market reforms back in the 1980s. Their conclusions show the success of the grain market liberalization in Mali in integrating markets. Conversely, policy in livestock development has since the colonial time lacked a clear orientation in terms of livestock marketing and market information gathering and dissemination (Ministry of Livestock and Fisheries, 2004). As opposed to the Cereal and Grain marketing boards that evolved from government control in 1989 to a private-led agency OMA (Agricultural Market Watch) in 1998, the livestock marketing agency changed only names but remained under government (Dembele and Staatz, 2004). However the recent partnership (2007) between Texas A&M University and Global Livestock CRSP started the Mali Livestock and Pastoralist Initiative (MLPI) to develop a livestock market information system (LMIS) (Angerer et al., 2010). The project introduced the use of cell phones to disseminate livestock price information to cattle producers and traders in an attempt to improve market transparency. The goal of the MLPI project is to develop reliable and timely livestock market information in the country and provide a basis for livestock producers and traders to make informed marketing decisions and reduce risk. As Angerer et al. (2010) put:

"*The implementation of the LMIS in Mali represents first time that near real-time market information on livestock has been available to the public….* "

This paper will assess the impact of the use of cell phones on the level of cattle market integration in Mali and determine where the price leadership is discovered.

The study of co-movement of prices between markets will serve as a determinant factor of market integration. Structural breaks analysis will be conducted to detect if there is any change in market price structure due to the introduction of cell phones.

The paper is divided into four parts. Section one introduces the paper; section two describes the study area; section three presents the theoretical model and method and section four discusses the results and conclusions.

Study area

The six markets under study are described as follows:

Kidal: is located in the desert region of Kidal, district of Kidal. The market receives on average between 64 and 228 cattle each month;

Gossi: located in the Tombouctou region, district of Gossi, the market receives on average between 265 and 541 cattle each month;

Konna: located in the Mopti region, district of Konna, the market counts on average between 350 and 680 heads of cattle each month;

Wabaria: is located in the Gao region, district of Gounzoureye. Wabaria market counts on average 942 and 1050 heads of cattle each month;

Kati: is located in Koulikolo region, district of Kambila. The monthly average number of cattle traded in Kati market ranges between 4300 and 8463 making Kati the third largest livestock market in Mali.

Niamana: located in the Koulikolo region, district of Kalabancoro (20 km east of Bamako) is the largest cattle market in Mali. The average number of cattle traded in Niamana varies from 21300 and 26610 heads each month. Niamana is supplied by all regions of Mali except Kidal. The other markets above are mostly supplied by local village markets. Except the market of Kati, all the other markets are located on the main road Bamako-Gao-Kidal.

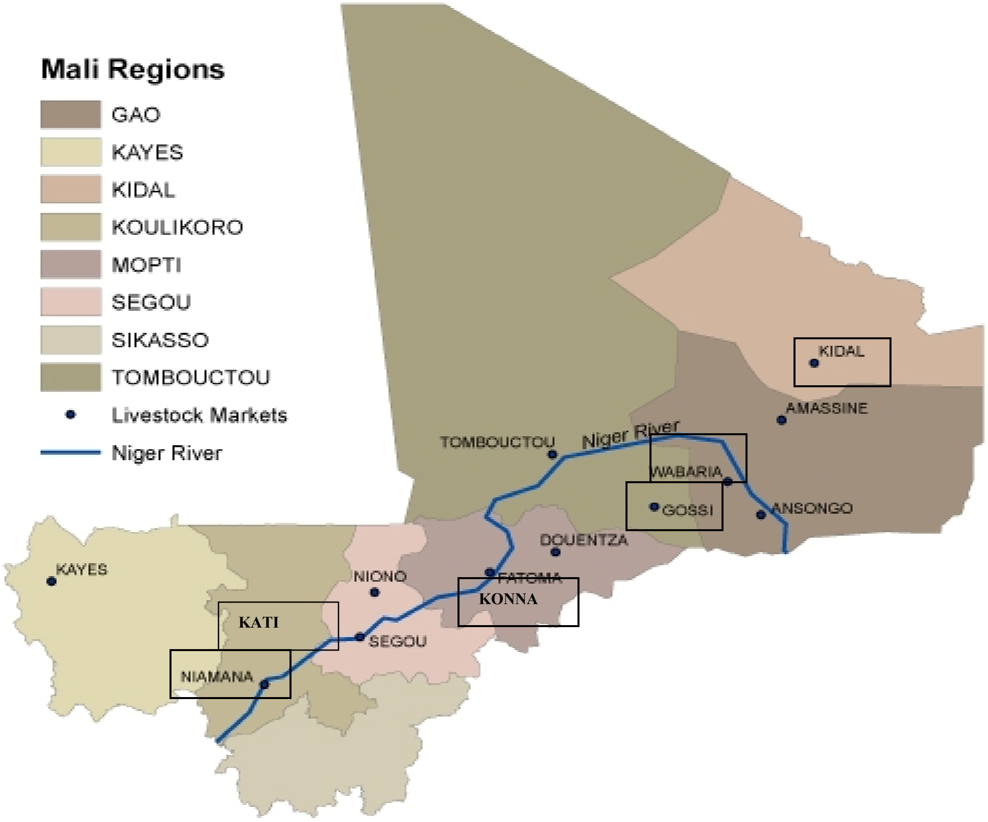

Figure 1. Map of eight administrative regions of Mali and the cattle markets under study

Theoretical model and methods

In an integrated market prices of cattle observed in different locations at one point in time will differ by the amount up to the transaction costs of the cattle from one location to another as suggested by the Law of One Price (LOP) (Dawson and Dey, 2002). The LOP simply put is a situation where commodity arbitrage ensures that each good has a single price (defined in a common currency unit) throughout the world. One way of finding empirical evidence of market integration and price convergence has been achieved in the context of the Law of One Price (Bukenya and Labys, 2005).

The LOP is one property of the competitive spatial market equilibrium. If trade occurs between two locations and is unrestricted, the marginal trader earns zero profits and prices in the two markets co-move. Baulch (1997) reports four econometric approaches to test for spatial market integration: LOP, Ravallion model, Granger-causality, and co-integration. Recent research have used time series techniques to discuss issues on spatial market integration, causality and speed adjustment from disequilibria (Dawson and Dey, 2002; Bukenya and Labys, 2005; Stockton et al., 2010). We use the error correction model and co-integration to determine the level of cattle market integration in Mali.

The Error Correction Model (ECM)

According to Samuelson (1971) agricultural products (for example wheat), which can be carried over through time and space, are subject to arbitrage and hard to predict due to certain factors such as production fluctuation. Their prices are stochastic speculative prices that follow a Brownian motion model and therefore are non-stationary. This applies as well to the cattle market prices. However, even though the prices are individually non-stationary, we expect prices for the same type of cattle and grade (size, fatness) in our six markets under study to move together or in other terms to be co-integrated. If we assume the existence of co-integration, the data generating process of P_t (price at time t) can be appropriately modeled in an error correction model (ECM) with k-1 lags which is derived from a levels vector autoregression (VAR) with k lags:

$$\Delta P_t = \Pi P_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta P_{t-i} + \mu + e_t \qquad \text{where } t = 1,\ldots,T\ ;\ e_t \sim \text{Niid}(0, \Sigma) \qquad (1)$$

Where Δ is the difference operator ($\Delta P_t = P_t - P_{t-1}$), P_t is (6x1) vector of weekly prices at time t from each of the six markets; Γ_i is a (6x6) matrix of coefficients associating price changes lagged i period to current changes in prices; $\Pi = \alpha\beta'$ is (6x6) matrix coefficients associating lagged levels of prices to current changes in prices (or 6x7 if a constant is in the co-integration space) and ε_t is a (6x1) vector of white noise innovations.

The co-movement of prices can exhibit long-run and short-run relationships. The long-run structure can be analyzed through testing hypotheses on the β; the short-run structure can be studied through testing hypotheses on α and Γ_i (Johansen and Juselius, 1994). The contemporaneous structure can be examined through structural analysis of e_t or more conveniently through the directed graph analysis of the covariance matrix (Σ) (Vitale and Bessler, 2006).

The number of co-integrating relations, r, can inform us on the long-run structure of market interdependence. The rank of Π (i.e. row rank of β) determines the number of co-integrating vectors r. To determine this number, trace tests on the eigenvalues of Π are used in our six markets study (Enders, 2010).

Exclusion tests and weak exogeneity tests are carried out to find out which markets are not parts of the co-integrating space and which ones that do not respond to shocks.

It is widely accepted that, like the standard VAR models, individual coefficients of the ECM are difficult to interpret since the coefficients estimated are those of the reduced form equation and not the original structural equation model. Under such cases, innovation accounting may be the best description of the dynamic structure (Enders, 2010; Swanson and Granger, 1997). The innovation accounting techniques used are forecast variance decomposition and impulse response function.

Directed Acyclic Graph and PC algorithm

Co-integration methods are important in determining the co-movements of variables but they do not necessarily inform us on the causality between variables, hence the use of directed acyclic graphs (DAG) method to explain causal relationship between variables. A directed graph is a diagram that represents a causal flow among a set of variables

(Vitale and Bessler, 2006). Capital letters such as $X_1, X_2, \ldots, X_n$ are used to represent variables and lines (edges) with arrowheads at one end represent causal flows (e.g. $X_1 \rightarrow X_2$ indicates X_1 causes X_2) (Haigh and Bessler, 2004). The graphs with directed edges ($X_1 \rightarrow X_2$ is called a directed edge) are of importance since they show the direction of the causal flow. Graphs with no cycles are said to be acyclic.

The important characteristic of the DAG method is their conditional independence property put on variables to determine different causal flows between variables (Pearl, 1995; Haigh and Bessler, 2004). The basic idea used to determine the direction of causal flows for a set of observational variables is that of "screening off" that was formalized in terms of d-separation by Pearl (2000) (Hoover, 2003; Vitale and Bessler, 2006). For instance, for three variables A,B, and C, if B is a common cause of A and C (A←B→C), then the unconditional association between A and C will be non-zero given the fact that both A and C have a common cause in B (diagram called causal fork). By measuring linear association between A and C, we find that A and C have non-zero correlation. However, if we condition on B, the partial correlation between A and C will be zero. Common causes "screen off" association between their common effects.

Spirtes et al. (1993) incorporated the d-separation into an algorithm (PC algorithm) for determining causal flows among a set of more than three variables and building directed graphs. Basically, the PC algorithm is a sequential set of commands that starts with an unrestricted graph where every variable is connected to every other variable and proceeds step-wise to remove edges between variables that are not correlated and direct causal flows for those which are associated.

Data

Data on cattle prices are used to evaluate the market integration process after cell phones were introduced in livestock markets to disseminate price information. In this study we analyze weekly data on price of cattle collected from November 2008 to September 2010 in six markets of Gossi, Kidal, Konna, Niamana, Wabaria and Kati. The category of cattle targeted in this study is that, of adult male with a fat body condition (or medium where fat is not available) from Zebu breed. In some instances where information on adult male were lacking we used data on adult castrate fat. Due to dry condition in Kidal fat animals are not common we used instead animals of medium category for this study. The data were collected under the MLPI (Mali Livestock and Pastoralist Initiative) project after the introduction of cell phones to collect market prices.

Results and discussion

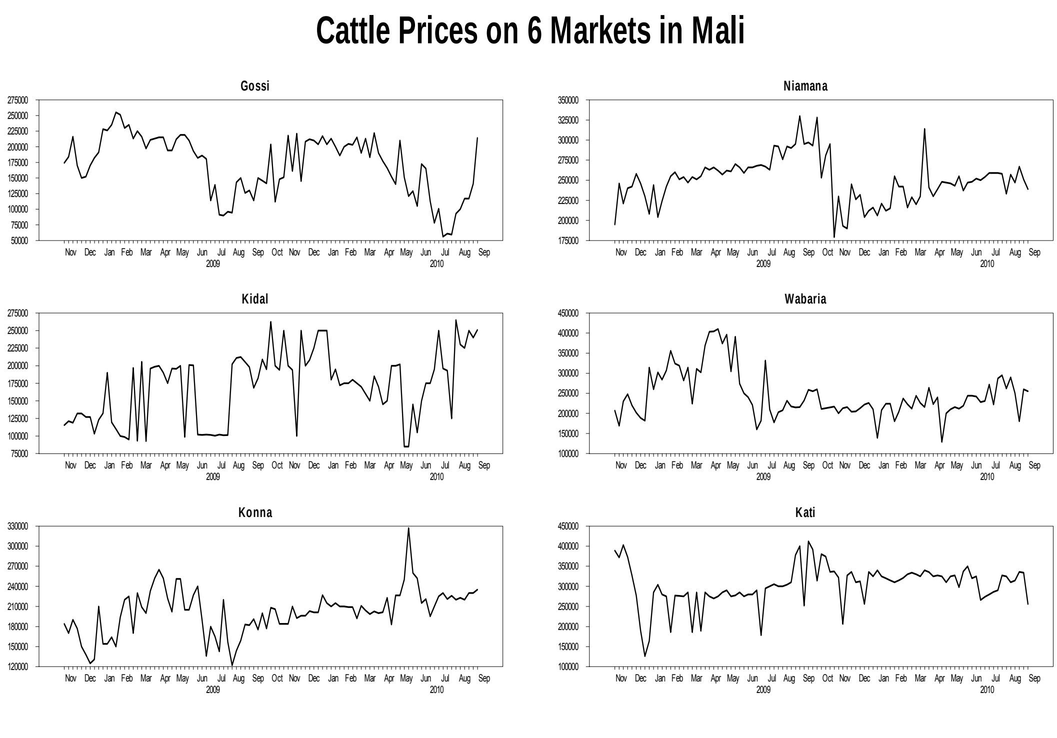

Figure 2. Price series in levels for six cattle markets in Mali

The figure 1 above shows the evolution of cattle prices over nearly two years on six markets scattered around the country. There is no clear similar pattern of variation among the price series in all six markets. However the prices seem to follow a more or less random walk mixed with a tendency for the series to return to their long-run mean (mean reversion). We notice more particularly a sharp drop in price between May and August 2009 in Kidal due to the predominant presence on the market of medium fat immature male cattle during the normal dry period of the year. This pattern is also observed for the markets of Gossi, Konna and Wabaria where a severe drought hit these regions around the period of June 2009 (Dial, personal communication).

Table 1. Summary statistics on prices of cattle from 6 markets in Mali, 2008-2010

Market	**Mean**	**rank**	**SD**	**rank**	**CV**	**rank**
Gossi	171550	6	47609.24	4	27.75	2
Kidal	171211	5	49739.7	3	29.05	1
Konna	202100	4	33828.25	5	16.73	5
Niamana	250134	2	28254.66	6	11.29	6
Wabaria	243567	3	61814.39	1	25.37	3
Kati	302808	1	50966.18	2	16.83	4

The descriptive statistics in table 1 presents the mean, standard deviation, coefficient of variation and their respective rank in order from the highest (1) to the lowest (6) for 6 cattle markets in Mali from November 2008 to September 2010. Kati has the highest average price followed by Niamana and Wabaria. Those three markets are the largest in this group of markets in terms of quality (fatness) and number of heads present at the market place. The last two markets, Gossi and Kidal have few animals and qualitatively the animals are medium to thin with regard to body fat. This is due (mainly for Kidal) to the dry conditions of the land (desert region). We also notice a lot of variability in price in Kidal and Gossi for the reasons presented above.

Table 2. Test of non-stationary on prices of cattle from 6 markets in Mali, 2008-2010

	Dickey-Fuller		Augmented Dickey-Fuller		
Market	t-test	Q (p-value)	t-test	k	Q (p-value)
Gossi	-0.75054	37.72 (0.000)	-2.68317	1	11.79 (0.29)
Kidal	-0.01092	29.25 (0.001)	-3.71786	1	2.05 (0.99)
Konna	-1.40509	23.22 (0.009)	-3.08419	1	7.05 (0.72)
Niamana	-0.10394	42.57 (0.000)	-2.25513	1	7.09 (0.71)
Wabaria	-0.75171	41.05 (0.000)	-2.55701	1	8.57 (0.57)
Kati	-1.00102	32.60 (0.000)	-3.44429	1	16.64 (0.08)

Table 2 presents the Dickey-Fuller and Augmented Dickey-Fuller (ADF) tests results on levels of cattle prices in six markets of Mali from 2008-2010. The null hypothesis on each levels test is that the price in each market is non-stationary. Since the ADF test is more preferred than DF for unit root test, we discuss the ADF test results. The tests show that three series among the six (in bold) are non-stationary while three others are stationary given that the t-statistic is less than -2.89 (5% critical value) for the stationary series and greater than -2.89 in the remaining non-stationary series. Given that the Dickey-Fuller tests in general are known to have low power, the ERS test (unit root test) was performed to verify and confirm the stationarity of the price series. The Elliot, Rothemberg and Stock or ERS test (GLS version) which is a modification of ADF test is believed to have a maximum power and to be efficient. The null hypothesis is that of unit root. The results show that we fail to reject the null hypothesis of integration in all six markets for the case where we do not consider a deterministic trend in the equation. In other cases (constant or trend), we reject the null of unit root. The p-value on Ljung-Box Q statistic applied to the residuals from each ADF test show that the residuals are not auto-correlated. We fail to reject the null hypothesis of non auto-correlated residuals.

A lag length test was performed to determine the maximum number of lag for the model. Schwartz loss test was carried out and the results showed a minimum of one lag.

Table 3. Trace test on cattle prices from 6 markets in Mali, 2008-2010

Ho: r	**T***	**P-value***	**D***	**T**	**P-value**	**D**
=0	150.73	0.000	R	164.33	0.000	R
≤1	97.98	0.000	R	104.94	0.000	R
≤2	63.14	0.005	R	66.49	0.002	R
≤3	38.90	0.017	R	40.32	0.011	R
≤4	17.64	0.111	**F#**	18.01	0.099	**F#**
≤5	8.59	0.064	F	8.64	0.063	F

D= decision

Even though the individual series are non-stationary, certain linear combinations of prices in levels from different markets may be stationary, or co-integrated. Table 3 shows trace tests results for co-integration. The trace test determine the appropriate number r of co-integrating vectors (rank test) by a sequential testing procedure as described in Johansen (1992, p.390) and Juselius (2006, p.135). First we begin by testing if all six roots are unit roots (r=0) with (marked with asterisk) and without a constant in the co-integrating space. If rejected we proceed with the testing whether the five roots are unit roots and continue until we fail to reject the null hypothesis. This occurs at r=4 (marked with a # sign) suggesting that we have four co-integrating vectors with a constant in the co-integrating space and two common trends.

Despite the four long-run stationary relations between markets, one or more markets may not be a part of these four vectors. To find the series that are not part of the co-integration space we run an exclusion test. Table 4 shows that none of the series is excluded from the co-integration space.

Table 4. Tests on exclusion for each market from co-integrating space, 2008-2010

Market	Chi-Squared test	p-value	Decision
Gossi	24.50	0.000	R
Kidal	27.45	0.000	R
Konna	13.67	0.008	R
Niamana	25.09	0.000	R
Wabaria	23.21	0.000	R
Kati	43.95	0.000	R
Constant	16.51	0.002	R

Table 5 presents a test of weak exogeneity on each market. The goal of this test is to find out which market responds to shocks in the co-integrating space. Among the six markets, one market, Konna, exhibits the weak exogeneity property. The remaining five markets react to perturbation in the co-integrating space to restore the long-run equilibrium.

Table 5. Tests on weak exogeneity for each cattle market, 2008-2010

Market	Chi-Squared test	p-value	Decision
Gossi	23.308	0.000	R
Kidal	11.09	0.025	R
Konna	6.72	0.151	**F#**
Niamana	16.86	0.002	R
Wabaria	17.41	0.002	R
Kati	28.10	0.000	R

Equation (4) presents the contemporaneous correlations between price innovations in each market. Each market name is abbreviated by writing the first three letters of the market in the order: Gossi, Kidal, Konna, Niamana, Wabaria and Kati

$$\begin{matrix} \text{GOS} & \text{KID} & \text{KON} & \text{NIA} & \text{WAB} & \text{KAT} \end{matrix}$$

$$\text{Corr}(e_t)=\begin{bmatrix} 1.000 & & & & & \\ 0.209 & 1.000 & & & & \\ -0.168 & -0.307 & 1.000 & & & \\ -0.202 & -0.166 & -0.089 & 1.000 & & \\ -0.202 & -0.337 & -0.009 & 0.102 & 1.000 & \\ -0.131 & 0.072 & -0.096 & 0.436 & 0.079 & 1.000 \end{bmatrix} \quad (4)$$

From the matrix above we observe that contemporaneous correlation between markets is weak with all values under 0.5 (the highest being 0.436). The highest correlation is between Niamana and Kati (0.436), two closest and large cattle markets. The lowest correlation is between Konna and Wabaria (-0.009).

Directed Acyclic Graph (DAG) method was used to evaluate the contemporaneous correlation between innovations (See Figure 2). The results show that the market prices are weakly correlated; we have very few directed edges between different markets. Kidal has no connection with any of the market, which can be explained by its isolated location in the desert region.

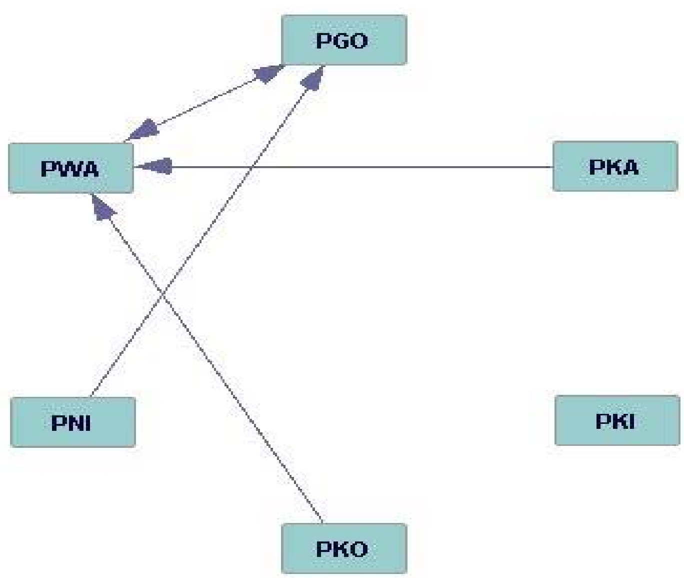

Figure 3. Causal flow found with PC algorithm at 5% significance level, on innovations from an Error Correction Model on cattle price from six markets in Mali, 2008-2010

The forecast error variance decomposition was analyzed to see how much change in the future (uncertainty) of one market price is caused by another market.

Table 6. Forecast error variance decomposition on cattle prices in Mali, 2008-2010

Horizon	GOSSI	KIDAL	KONNA	NIAMANA	WABARIA	KATI
			(Gossi)			
0	100.000	0.000	0.000	0.000	0.000	0.000
1	60.303	8.275	2.253	4.384	0.099	24.686
4	31.491	7.299	1.851	7.715	5.015	46.628
8	23.925	6.108	0.812	9.902	8.032	51.221
			(Kidal)			
0	2.621	77.588	8.123	0.000	11.668	0.000
1	4.624	64.043	21.858	0.097	8.984	0.394
4	5.685	39.940	37.701	0.795	4.570	11.310
8	9.370	27.017	32.528	2.782	3.262	25.042
			(Konna)			
0	0.000	0.000	100.000	0.000	0.000	0.000
1	0.000	6.644	90.296	0.033	1.683	1.344
4	0.638	9.212	84.520	0.063	1.578	3.988
8	2.155	11.053	76.561	0.309	1.005	8.917
			(Niamana)			
0	2.552	3.451	0.561	74.971	0.519	17.947
1	13.282	4.070	3.226	44.773	3.269	31.380
4	17.156	2.994	4.507	20.568	9.070	45.704
8	18.554	2.694	5.981	14.437	11.018	47.316
			(Wabaria)			
0	0.000	0.000	0.000	0.000	100.000	0.000
1	0.580	3.611	1.662	6.965	85.736	1.446
4	7.295	3.290	5.201	8.273	59.664	16.277
8	13.043	2.573	7.782	10.015	35.448	31.139
			(Kati)			
0	0.000	0.000	0.000	0.000	0.000	100.000
1	5.091	0.532	1.189	2.988	7.449	82.751
4	9.855	1.804	4.563	6.566	8.726	68.487
8	14.547	1.928	7.282	9.328	10.666	56.248

Table 6 presents the results of the forecast error variance decomposition on cattle prices in each of the six markets at horizon of zero, 1 week, 4 weeks and 8 weeks ahead. It is the percentage of forecast error uncertainty in one market accounted for by earlier innovations in other markets. For example the innovations associated with current prices in Gossi, Konna, Wabaria and Kati markets are solely explained by the own-price shocks. However, innovations associated with current price in Kidal and Niamana are explained by shocks from Wabaria and Konna (12% and 8% respectively) for Kidal and by Kati (18%) for Niamana. At one horizon, only Konna, Wabaria and Kati experience less shocks from other markets where the percentage of variation in price, explained by innovations from other markets range between 10 and 18. At longer horizon (8 weeks), all market prices are influenced by other market prices innovations except Konna that accounts for 76% of price variation by its own-price shocks and 24% by innovations from other markets. The results indicate Konna to be exogenous across time which categorizes it as a less risky market in terms of price variation. This is supported by the results in table 5 where Konna is identified as weakly exogenous and in table 1 where Konna has the second lowest coefficient of variation of price.

Even though cattle markets in Mali showed a long-run interdependence by co-movement the results above indicate limited price transmission and interdependence, at least contemporaneously, among the markets. This may be due to the following reasons. First the markets considered in this study are spread out from South-west to North-east along the axis road Bamako-Gao-Kidal (1200 km or 720 miles). High transportation cost may inhibit any attempt to trade cattle across markets specifically for Kidal market isolated in the desert region. Second the learning process in using cell phone improves over time and its impact in reducing uncertainty in the cattle market increases with time.

In terms of price leadership, Konna emerges as a possible source of price signal. This is supported by the fact that Konna is exogenous and located half way along the line joining the cattle markets under study (axis road Bamako-Gao-Kidal). This location may be strategic in stabilizing the cattle prices in Konna and serving as a reference of price in cattle markets located upstream and downstream of Konna.

Structural break analysis

We tested for structural break to check whether the introduction of cell phones in cattle markets contributed to market integration. Several methods were used for this purpose: recursive residual test, recursive trace tests, Box M test and the Bai-Perron test.

The results, from the Bai Perron test, show different break points dates for different markets. Wabaria, Kati, Kidal and Niamana have break point dates between May and September 2009 while Gossi and Konna have their date between April and May 2010. These results are not conclusive regarding the impact of cell phones on structural change but suggest that other events may have caused the break points. One possibility is an extreme drought that hit the country from the late 2009 to April 2010 (Dial, Personal Communication).

The recursive residual test shows no particular pattern of structural break in all the price series except for Kati where the graph suggests a possible break around April 2010 (Figure 4). This may not suggest a change in structure due to cell phone but does support earlier observations on the consequences of extreme drought that started late 2009 until April 2010. To further check for structural change, we run a Box M test to compare covariance matrices between the first half and the second half period of the entire dataset. The χ^2 statistic of 147.12 found is greater than the 5% critical value of 32.67 (df=21), which rejects the null hypothesis of equal covariance matrices for the two periods suggesting some change in the structure occurred between these two sub-periods.

The recursive trace test (figure 5) was run to analyze how the market integration evolved over time by counting the number of co-integrating vectors above the unit line. We note that the number of co-integrating vectors increased over time. For instance, there is only one co-integrating vector from May 2009 to August 2009. After September 2009 the number increases to two co-integrating vectors and then to three in November 2009. Around June 2010, we have all four co-integrating vectors. This is a sign that over time the market integration progresses as the exchange of information between cattle traders and producers expands. At the beginning of the introduction of cell phones few markets were integrated but after nearly two years of cell phone use, more markets are integrated, suggesting less uncertainty in the marketplace and greater price information exchange.

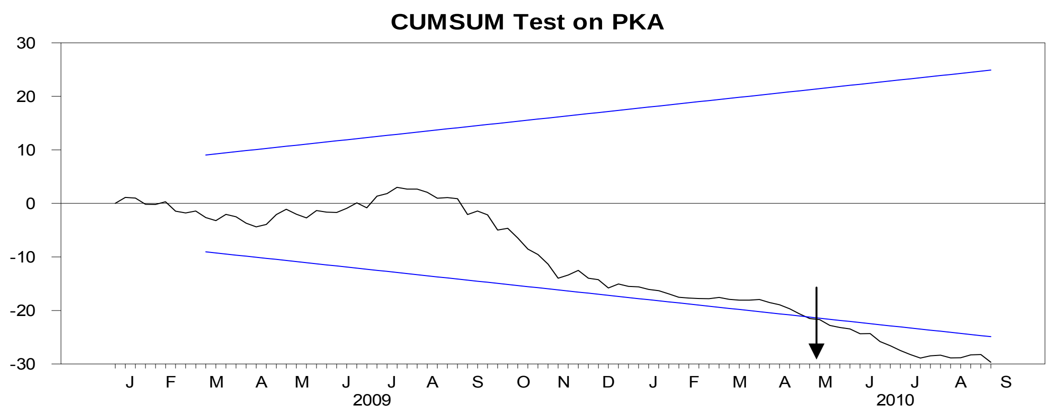

Figure 4. Cumulative sum of recursive residuals plotted against the upper and lower bound of the 95% confidence interval for Kati market

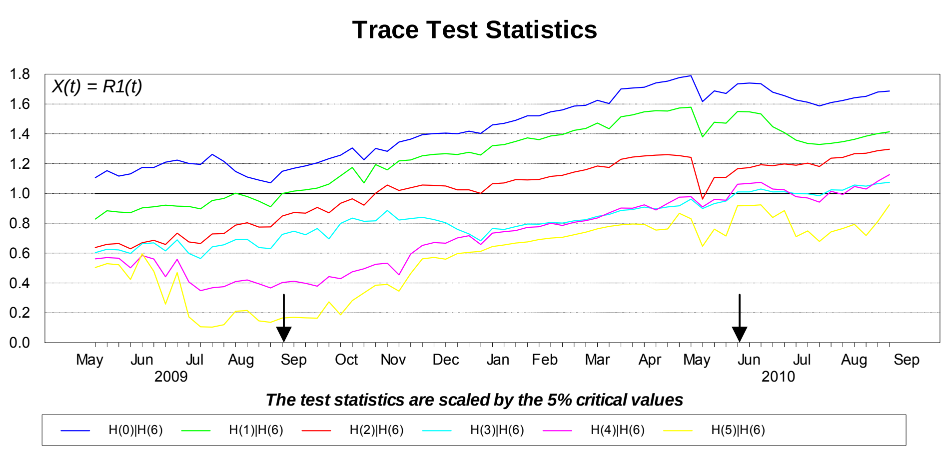

Figure 5. Recursive trace tests statistics scaled by 5% critical values

Conclusions

Weekly data on male adult cattle prices in Mali are studied from November 2008 to September 2010 in six livestock markets. The goal is to analyze cattle price interdependence in the six markets to determine the level of market integration after the introduction of cell phones to disseminate price information. The results show that the six markets are linked together in four long-run relationships. Contemporaneous correlations between price innovations in each market show a weak relationship between markets. The DAG findings corroborate this result and show few directed causal flows between markets. The forecast error variance analysis indicates that price variations in most of the markets are explained by own-price shocks in contemporaneous time. However this percentage of price variation diminishes in longer horizon for all other markets except Konna. The latter emerges as a potential source of price leadership given its exogeneity and a low coefficient of variation. The structural break tests show no regular pattern of date associated with the introduction of cell phones in the price structure except some impact that may have been caused by a severe and extended drought in 2009 and 2010. However, the recursive trace tests show regular pattern of progressive market integration over time possibly as a result of the cell phone use to disseminate price information. The market information system put into place by MLPI is making good progress in integrating the cattle markets by reducing uncertainty and risk in the markets thanks to the use of cell phones. Further studies, prior to the introduction of cell phones in 2008, are recommended to confirm the impact of improved communication tools (cell phones) to disseminate price information and help in market integration process.

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