Spatial dynamics and determinants of Liberian rice market integration

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Abstract

Monthly wholesale prices of imported rice were used to estimate the spatial dynamics of eight local markets and the impact of infrastructure on spatial market integration. The results, based on threshold and linear error correction models, indicate that Liberian rice markets are spatially integrated, with four main price-transmission markets, Red-Light, Gbarnga, Saclepea and Buchanan. Red-Light is the main entry market for imported rice. Its estimated period of outgoing price transmission is about five months, with bad road conditions the likely impediment to more complete market integration. In 12 of the 17 long-run, related market pairs, negative and positive price changes are transmitted symmetrically. Asymmetry in five market pairs is potentially a result of localised market power. Overall, integration responds positively to improved roads and negatively to spatial separation and quality of communication. Markets could be better integrated by improving transportation and market infrastructure.

Key words: market integration; asymmetric transmission; Liberia; rice

1. Introduction

More than 50% of rice for consumption in Liberia is imported (FAO 2016). Liberia and other African nations responded to the global rice price crisis of 2008 with National Rice Development Strategies, primarily to address supply-shifting investments (Demont 2013). For these investments to be successful, local markets need to be integrated so that price incentives are transmitted to producers. Systemic urban bias in policies unfavourable to agriculture and the rural economy results in import dependency for food staples such as rice in Liberia. Understanding the nature of market integration, particularly in post-crisis Liberia, is important for policy makers. Policies to improve the transmission of price signals to rice consumers and producers are essential to enhance food security and to develop domestic production that can compete with imports. The present research is the first to estimate the degree of market integration of local, Liberian markets for imported rice.

Over half of Liberia's population lives in urban areas – particularly Monrovia – where most people rely on imported rice. Domestic production, mainly upland rice produced under slash-and-burn cultivation, is primarily consumed at home (MOA 2010). Rice demand is price inelastic and therefore vulnerable to international price volatility, and its distribution in Liberia is constrained by the poor road infrastructure and weak household purchasing power (Samba *et al*. 2013). The price of rice has a significant impact on poverty: a 20% increase in Liberian consumer rice prices has been estimated to increase the poverty rate by 4.2% (Tsimpo & Wodon 2008).

As a key to successful market liberalisation and price stabilisation policies, improved market price integration would reduce the policy challenge to manage prices in local markets. Changes in supply or demand conditions at the central market would be transmitted to local markets more quickly, making the need to intervene in local markets less likely. Understanding the dynamics of price transmission among markets enables policy makers to respond to price shocks. Such an understanding can could guide the needed infrastructure investments to reduce transaction costs (Tsimpo & Wodon, 2008).

Using the monthly retail prices of imported rice from eight local markets, we (1) estimated the extent to which markets respond to price changes in other markets using threshold and linear error correction models; (2) tested symmetric price transmission, given the direction of long-run causality of given pairs of markets; and (3) identified the determinants of market integration using a regression model approach. Most market integration studies involve domestically produced commodities. This study differs because the commodity of interest is strongly influenced by international price movements.

2. Background information and literature review

2.1 The Liberian rice market

The rice belt of Liberia includes Nimba, Bong and Lofa counties, which account for approximately 60% of domestic rice production (see Table 1). Major market towns in these counties are Saclepea, Gbarnga and Voinjama respectively. Total rice imports in 2013/2014 were 300 000 MT against 160 000 MT of local production. Before 2011, butter rice from China dominated the rice import market (Reynolds & Field, 2009); however, since the latter part of 2011, parboiled long-grain rice has become the dominant imported rice type, accounting for 94% of all rice imported. Since 2008, three private importers have accounted for over 75% of all rice imports to Monrovia, making the market structure highly oligopolistic (Wailes 2015). The oligopolistic structure is partly explained by: (1) import permit requirements for importers to maintain national rice reserve in their warehouses; (2) the inability of Liberian financial institutions to furnish traders with "letters of credit" to facilitate buying rice from exporters; and (3) domestic banks not being competitive on interest rates relative to international banks (Ah Poe *et al*. 2008).

Table 1: Liberian rice economy at the county level in 2012

County	Major market		Rice households	Area (ha)	Yield (kg/ha)	Share (%)
	Name	Type				
Bomi	Tubmanburg	R	5 300	7 260	1 206	2.5
Bong	Gbarnga	W/R	35 560	49 070	1 043	21.0
Gbarpolu	Bopolu	R	10 070	12 690	1 271	5.4
Grand Bassa	Buchanan	W/R	11 790	14 070	1 272	5.2
Grand Cape Mt	Robertsport	R	4 770	7 550	1 102	3.1
Grand Gedeh	Zwedru	W/R	9 800	10 780	1 211	4.4
Grand Kru	Barkclayville	R	8 160	8 980	1 206	3.5
Lofa	Voinjama	R	33 480	41 760	1 160	17.7
Margibi	Kakata	W/R	6 540	6 360	1 261	2.6
Maryland	Pleebo	W/R	7 400	7 920	1 212	3.1
Montserrado	Red-Light	W/R	6 700	6 520	1 162	2.5
Nimba	Saclepea	R	49 460	52 520	1 161	21.2
River Cess	River Cess	R	5 930	5 120	1 201	1.8
River Gee	Fish Town	R	5 840	7 700	1 021	3.1
Sinoe	Greenville	R	7 770	8 080	1 182	2.9

Source: MOA 2010

A market flow map for imported rice in Liberia is presented in Figure 1. Rice importers sell in US dollars to wholesalers located in the Red-Light market in Monrovia – the primary terminal for imported rice – who in turn sell to retailers (also in US dollars) in regional markets, including Buchannan, Gbarnga and Zwedru. The retailers sell in Liberian dollars to 'micro-retailers', mainly women who sell rice by the cup to the final consumer (Ah Poe *et al*. 2008). South-eastern Liberia has a major wholesale market in Pleebo, which relies on imported rice supplies from neighbouring Côte d'Ivoire. The informal trade with the Ivoirians also provides vital imported rice supplies to the chronically food-insecure Liberians in these areas (Koiwou *et al*. 2007).

Given the importance of informal, cross-border trade with the Ivoirians, the more recent political instability and violent conflicts in Cote d'Ivoire have significantly affected the food security status of south-eastern Liberians. The influx of refugees from Guinea and Cote d'Ivoire has had a major impact on food security in the Liberian counties, particularly Nimba, Grand Gedeh, Maryland and Lofa (Koiwou *et al*. 2007). The arrival of refugees from Cote d'Ivoire has resulted in significant shipments of food and shelter supplies to meet the humanitarian crisis in Saclepea and Zwedru since January 2010 (UNHCR, 2011).

Liberia's National Rice Development Strategy (LNRDS), an initiative of the Government of Liberia (GoL), aims to improve productivity on smallholder rice farms through a value-chain, integrated approach in order to ensure national food security. Under the LNRDS, the GoL has identified a number of constraints to increasing rice production. Notable among these constraints is inadequate infrastructure in terms of transportation (Wailes 2015). Currently, value chains are undeveloped and markets are inaccessible because of the lack of rural infrastructure, including limited and dilapidated roads (LASIP 2010). The Liberia Agriculture Sector Investment Program (LASIP 2010) asserts that farmers are unable to incorporate appropriate information into production and marketing decisions due to the poor linkage between producers and markets. One of the specific objectives of LNRDS is to increase access to markets (Wailes 2015). As part of the present study, we investigated the degree of market integration and, in particular, how communications between markets and road infrastructure affect the spatial market price integration of the Liberian rice economy. Improving regional market price transmission and integration should further develop Liberia's rice value chain.

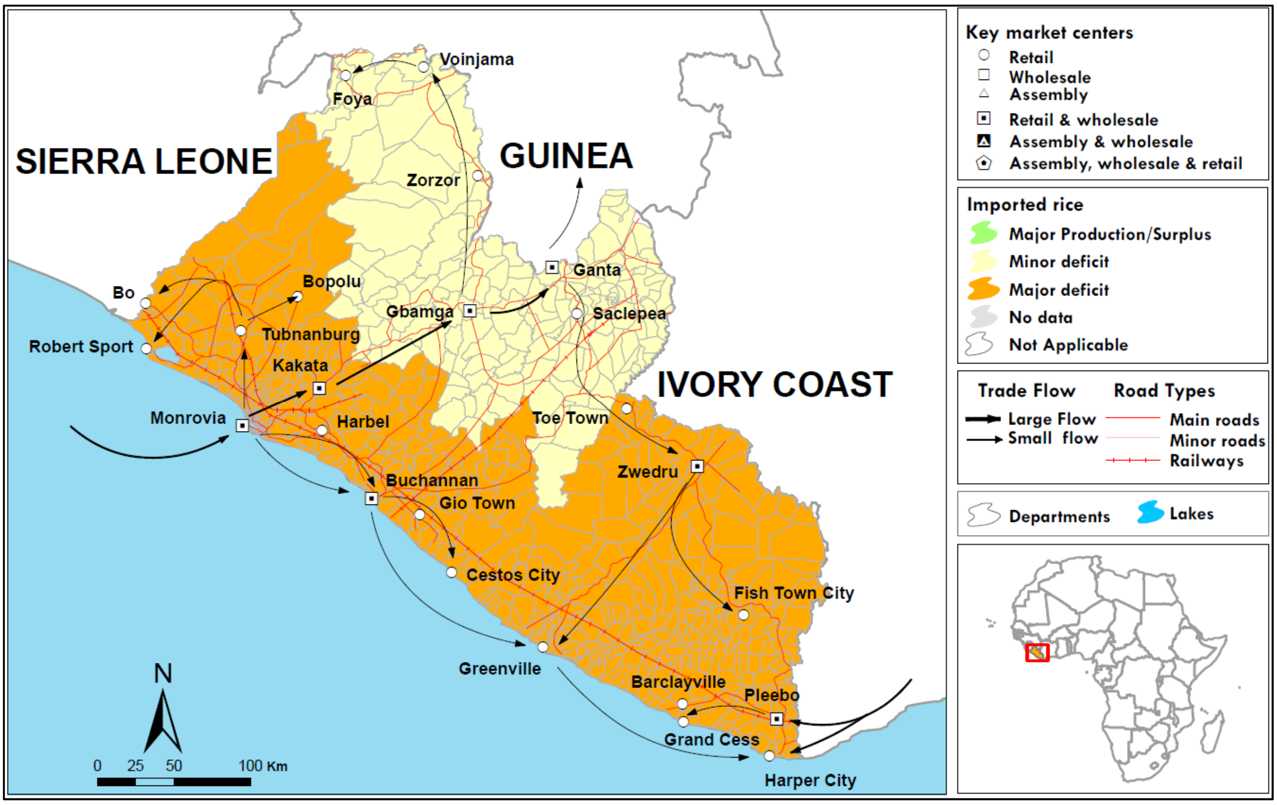

Figure 1: Imported rice market flow map for Liberia
Source: USID *et al*. 2010

2.2 Spatial market integration measurement techniques

Markets are integrated if commodity arbitragers act to ensure that prices in alternative markets differ by no more than marketing costs (Goodwin & Schroeder 1991), implying that geographically distinct markets are cointegrated. According to Engle and Granger (1987), if a vector of price series (P_t) is integrated by the same order and there exists a linear combination $\beta' P_t$ which is I(0), then the prices are said to be cointegrated with cointegrating vector β (parameters for the long-run equilibrium relationship). The null hypothesis of interest is that there is no cointegration. Johansen (1988; 1991) provides the trace test statistic for this hypothesis. Rejecting no cointegration implies that the components of P_t move together in the long run.

While cointegration is a long-run concept, policy focusing on shorter term objectives can be better calibrated by knowing the price adjustment dynamics of cointegrated markets. Price adjustment dynamics can be modelled as an error correction model (ECM), following Engle and Granger (1987). The ECM assumes that deviations from the long-run equilibrium are corrected linearly. Assuming that P_{it} $(i = 1,2)$ are integrated in the order of 1 and are cointegrated with cointegrating vector β and error term e_t, the ECM is:

$$\Delta P_{it} = \alpha_i + ECT_i e_{t-1} + \sum_m \gamma_{im} P_{it-m} + \sum_m \gamma_{jm} P_{jt-m} + u_{it}\ , \qquad (i = 1,2),\ (i \neq j) \qquad (1)$$

The operator Δ denotes first differences, and the subscript m indicates lags on the variables. The u_{it} are white noise error terms. The coefficients ECT_i $(0 < |ECT_i| < 1)$ are the error correction parameters that measure the rate at which deviations from previous periods are corrected by adjustments in P_{1t} and P_{2t} towards their long-run equilibrium relationship. Failure to reject the null hypothesis of $ECT_i = 0$ in both directions indicates no long-run relationship between P_{1t} and P_{2t}. If $ECT_i = 0$ is rejected, the average period (T_k) of adjustment of P_{1t} and P_{2t} within a certain range (r) of their long-run relationship can be estimated as $\ln(1-r)/\ln(1+ECT_i)$.

The ECM representation provides a framework for an asymmetric error correction model (AECM), proposed by Granger and Lee (1989), to test the asymmetry of the relationship between P_{1t} and P_{2t}. According to Meyer and Von Cramon-Taubadel (2004), asymmetry ('stickiness' of prices) can be classified into three categories. One category measures the magnitude of price responses to changes in another market that depend on the direction of the change. In this category, prices are typically transmitted with a higher magnitude for price increases than for price decreases. The second category measures the transmission speed: upward price changes are transmitted faster than downward fluctuations. The third category combines both magnitude and speed.

Asymmetry is typically applied to upstream and downstream – "vertical" – market levels, e.g. grain and flour. However, the idea can be extended to the spatial – "horizontal" – setting. Bailey and Brorsen (1989) and Meyer and Von Cramon-Taubadel (2004) suggest that spatial asymmetry could exist because of non-competitive markets, political intervention, market power and asymmetry in adjustment costs, information and price reporting. In addition, asymmetric spatial price transmission has been extensively documented in the literature (Bailey & Brorsen 1989; Mohanty *et al*. 1995; Von Cramon-Taubadel & Loy 1996; 1999; Abdulai 2000; Godby *et al*. 2000; Goodwin & Piggott 2001; Wondemu 2015).

The Granger and Lee (1989) AECM decomposes ECT into two parts depending on whether the deviation from the long-run equilibrium is positive or negative. The AECM is represented as:

$$\Delta P_{it} = \alpha_i + ECT_i^{+} e_{t-1} + ECT_i^{-} e_{t-1} + \sum_m \gamma_{im} P_{it-m} + \sum_m \gamma_{jm} P_{jt-m} + u_{it} \tag{2}$$

Parameter ECT_i is now superscripted by + or –, indicating response to positive or negative disequilibria respectively. Failure to reject the null hypothesis of $ECT_1^{+} = ECT_1^{-} = 0$ indicates no long-run relationship between P_{1t} and P_{2t}. Lastly, rejecting the null hypothesis of $ECT_i^{+} = ECT_i^{-}$ indicates asymmetry with respect to positive and negative price transmission between P_{1t} and P_{2t} (Meyer & Von Cramon-Taubadel 2004). In the context of this study, if e_{t-1} in equation (2) is positive, then P_{it} is considered being above its equilibrium value with respect to P_{jt}., and if negative it is considered below the equilibrium value. The average period of adjustments of P_{1t} and P_{2t} within a certain range (r) of the long-run relationship can be estimated as $\ln(1-r)/\ln(1+ECT_i^{s})$.

Equations (1) and (2) belong to the category of "linear" models in the sense that they assume that deviations from the long-run equilibrium are corrected linearly. However, non-linearity in market relationships may arise due to marketing costs, rigidities, market power or risk.

The threshold vector error correction model (TVECM) involves a relaxation of the linear model restrictions. Price adjustments need not occur instantaneously, but only when deviations exceed some critical threshold, allowing for an "inaction" or "no-arbitrage" band. Normally, the distinct regimes are identified by using the magnitude of the estimated long-run error term (Engle & Granger 1987; Serra *et al*. 2011). The TVECM assumes that the transition from one regime to another is abrupt and discontinuous (Chan & Tong 1986). For two *I(1)* time series (P_{it}), integrated of order 1 and cointegrated with cointegrating vector β and error term e_t, and assuming there exist three regimes of price transmission, a TVECM can be specified as:

$$\Delta P_{it} = \begin{cases} \theta_{1i} + \rho_{1i}e_{t-1} + \sum_m \varphi_{i1m}P_{it-m} + \sum_m \varphi_{j1m}P_{jt-m} + \varepsilon_{it} \\ \qquad e_{t-1} \le \psi_1 \quad (\boldsymbol{Regime\ 1}) \\ \theta_{2i} + \rho_{2i}e_{t-1} + \sum_m \varphi_{i2m}P_{it-m} + \sum_m \varphi_{j2m}P_{jt-m} + \varepsilon_{it} \\ \qquad \psi_1 < e_{t-1} \le \psi_2 \quad (\boldsymbol{Regime\ 2}) \\ \theta_{3i} + \rho_{3i}e_{t-1} + \sum_m \varphi_{i3m}P_{it-m} + \sum_m \varphi_{j3m}P_{jt-m} + \varepsilon_{it} \\ \qquad \psi_2 < e_{t-1} \quad (\boldsymbol{Regime\ 3}) \end{cases}, \quad (i = 1,2),\ (i \ne j) \tag{3}$$

The parameters ψ_1 and ψ_2 define two thresholds, such that $\min(e_t) < \psi_1 < \psi_2 < \max(e_t)$, where $\min(e_t)$ and $\max(e_t)$ are the lowest and highest values of observed e_t respectively. The parameters θ_{ki} are constant terms relevant to the k regimes, and the ρ_{ki} coefficients measure the speed with which deviations from previous periods are corrected by adjustments in P_{1t} and P_{2t} towards their long-run equilibrium relationship in the respective regimes (k) and direction (from i to j, or j to i). The φ parameters reflect the impacts of lagged price, and the ε_{it} are white noise error terms. Collecting the various parameters into $\mathbf{A}_1 = \theta_{1i}, \rho_{1i}, \varphi_{i1m}, \varphi_{j1m}$; and similarly for $\mathbf{A}_2$ and $\mathbf{A}_3$, the null hypothesis of a linear model (no threshold) is rejected if $\mathbf{A}_1 = \mathbf{A}_2 = \mathbf{A}_3$ does not hold. Similar to the ECM and AECM, the null hypothesis of no long-run relationship between P_{1t} and P_{2t} becomes $\rho_{1i} = \rho_{3i} = 0$, assuming that regime 2 is the inaction/no-arbitrage band.

The β, ψ, and ρ parameters have important interpretations. In spatial equilibrium, β is often taken to equal (1, -1), so that e_t measures the difference between P_{1t} and P_{2t} at time t. The threshold parameters – ψ_1 (ψ_2) – correspond to the marketing costs (from i to j, or j to i), and the ρ measures the speeds of adjustment. For a given pair of speed of adjustment parameters in regime k (say, $\rho_{ki} = -0.25$ *and* $\rho_{kj} = 0.30$), P_{1t} will fall (rise) in each period to correct 25% of any positive (negative) deviation from the equilibrium condition $e_t = 0$, and P_{2t} will correct by moving 30% in the respective opposite direction. Together, these changes imply a total adjustment of $\rho_{kj} - \rho_{ki} = \rho_k = 55\%$ per period. Thus, the average period of adjustment of P_{1t} and P_{2t} within a certain range (r) of their long-run relationship in the respective regimes can be estimated as $\ln(1 - r)/\ln(1 - \rho_k)$. In addition, rejecting the null hypothesis of $\rho_{11} = \rho_{31}$ (i.e. non equality of adjustment between regime 1 and 3) can be taken as an indication of asymmetry between P_{1t} and P_{2t}.

TVECM has been estimated using the profile likelihood estimator (Hansen & Seo 2002). However, this estimator is often biased and has a high variance, which can be amplified in small samples (Balcombe *et al*. 2007; Greb *et al*. 2014). As such, given our small sample size and these deficiencies, the regularised Bayesian (rB) estimator, developed by Greb *et al*. (2014) and explored in the context of TVECM by Greb *et al*. (2013), is used for estimating the TVECM.

Equations (1), (2) and (3) imply the existence of long-run Granger causality in at least one direction, which provides information on the direction in which price transmission is occurring between P_{1t} and P_{2t}. Granger causality in the long run can be identified by testing the hypothesis of no influence of e_{t-1}: Let δ_1 and δ_2 be the parameter space for $\{\rho_{k1}, ECT_1^i, ECT_1\}$ and $\{\rho_{k2}, ECT_2^i, ECT_2\}$ respectively.[1] In this testing framework, if (1) $\delta_1 = 0$ and $\delta_2 \ne 0$, then P_{2t} Granger causes P_{1t}; (2) $\delta_1 \ne 0$ and $\delta_2 = 0$, then P_{1t} Granger causes P_{2t}, and (3) $\delta_1 \ne 0$ and $\delta_2 \ne 0$, then P_{1t} *and* P_{2t} Granger cause each other in the long run (Granger 1988).

[1] The particular elements of δ_1 and $\delta_2$compared in testing depend on which of (1), (2) or (3) is selected.

3. Method of analysis and data

3.1 Market integration

Augmented Dickey-Fuller (ADF) statistics (Dickey & Fuller 1979) were computed for each pair of price series with and without a deterministic trend. For all possible market pairs integrated to the same order, the null hypothesis of no cointegration was tested against the alternative hypothesis of one cointegrating vector using the Johansen procedure (Johansen 1988; 1991). If no cointegration was rejected, a TVECM was specified as in equation (3) to estimate the speed of adjustment and long-run cointegrating relationship. If $\rho_{1i} = 0$ and $\rho_{3i} = 0$ were both not rejected, an ECM and its corresponding AECM were estimated. We then estimated the average period of adjustment of the respective pairs within 90% of their equilibrium long-run relationship, in addition to testing their long-run Granger causality and symmetry of response. All prices are modelled in natural logs.

3.2 Determinants of market integration

Prior market integration studies (Goletti *et al*. 1995; Ismet *et al*. 1998; Escobal & Cordano 2008) used a common methodology that is characterised by a two-stage approach: first estimate a measure of integration between two or more markets over a given time period, and then regress these measures on explanatory variables that mostly include – but are not limited to – marketing infrastructure, government intervention and production levels. The model for estimating the impact of determinants on the Liberian market integration can be written as:

$$C_{ijk} = \sigma_0 + \boldsymbol{\sigma}_k \mathbf{X}_{ij} + \varepsilon_{ijk} \quad k = 1, 2, \tag{4}$$

where C_{ijk} denotes the kth measure of market integration between market pair *ij*. The measures of market integration used are: trace statistics and the average lengths of adjustment between the lower and upper regime estimated from the TVECM. There are 28 possible observations for the trace statistics and 56 (28 × 2) lengths of adjustment. The vector **X** includes: (1) natural log of distance (measured in aerial km between pair *ij*); (2) transport infrastructure (measured as the percentage of paved roads, unpaved roads of 15 Mt capacity and unpaved roads of 5 Mt capacity for the shortest road between market pair *ij*); and (3) telecommunication infrastructure (measured as GSM coverage categorised as bad, good and better, based on the Africa Infrastructure Country Diagnostic (AICD; 2010).[2] Finally, (4) a refugee binary equalling one if the *ij* pair includes Saclepea or Zwedru and is included in **X** to capture the influence of refugee settlements. The ε_{ijk} are assumed to have the properties of the classical regression model. The null hypotheses of interest in equation (4) are that paved roads, relatively good roads, telecommunications infrastructure and refugee activities are negatively associated with market integration, while distance is positively associated with market integration.

3.3 Scope and source of data

Monthly prices of imported rice from January 2009 to December 2014 constituted the sample. The markets that were included are Buchanan, Gbarnga, Pleebo, Red-Light, Saclepea, Tubmanburg, Voinjama and Zwedru. The short sample length is a consequence of data availability. Rice price observations were collected from the Liberia Market Information System, a component of the Liberia Food Security Monitoring System. Observations on paved roads and distances between markets were computed using data retrieved from Styles (2013) and the World Food Program (WFP; 2011).

[2] These three categories are (1) "bad" when at least one of the markets is categorised as bad; (2) "good" when at least one of the markets is categorised as good and the other is not categorised as bad; and (3) "better" when both markets are categorised as better.

Over the eight markets and 72 months observed, 43 observations were missing. Values for the missing observations were synthesised by a two-step process. In the first step, the missing data was replaced with values reported in the monthly issues of the Liberia Market Price Monitor published by the WFP. In the second step, a linear interpolation of missing data was used whenever the first step failed.

4. Empirical results

4.1 Descriptive statistics of the price series

To remove inflation as a source of long-term trend, all price data were deflated using the monthly consumer price index retrieved from the IMF (2016). The mean real retail price of imported rice for the seventy-two months across all eight markets was 40.53 L$/kg, with a standard deviation of 3.68 L$/kg (Table 2).

Table 2: Descriptive statistics for real market rice price series (L$/kg), and augmented Dickey-Fuller tests for a unit root for real market rice price series, January 2009 to December 2014 (January 2009 = 100)

Series	Price (L$/kg)		ADF test with trend and intercept		ADF test with intercept only	
	Mean	Std. dev.	Levels	First Diff.	Levels	First Diff.
Buchanan	40.20	5.37	-2.62	-5.44***	-2.48	-5.47***
Gbarnga	39.10	4.36	-1.75	-4.75***	-1.66	-4.79***
Pleebo	44.45	6.00	-3.31*	-5.61***	-1.82	-5.62***
Red-Light	37.00	4.23	-2.20	-4.34***	-2.31	-4.32***
Saclepea	37.49	4.60	-3.01	-6.08***	-2.90*	-5.99***
Tubmanburg	37.95	5.39	-2.24	-5.70***	-2.33	-5.74***
Voinjama	42.79	3.93	-2.76	-6.51***	-2.26	-6.53***
Zwedru	45.22	5.55	-1.79	-4.97***	-1.96	-4.90***

Significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Lag length selection for unit root test based on Akaike Info Criterion: 0 to 3
Butter rice period span from January 2009 through July 2011, and parboiled rice from August 2009 through December 2014
Exchange rate as of January 2009: 1 US$ = L$ 64.44

The null hypothesis of a unit root for all eight price series cannot be rejected at $p < 0.05$ with or without trend in the test. When the ADF test was applied after differencing the series, the null hypothesis for all price series was rejected, indicating that all series are I(1) (Table 2). The trace test statistics suggest that 23 out of 28 of the market links are cointegrated at $p < 0.1$ or better.

4.2 Integration among Liberian rice markets

Long-run causality estimates for market pairs for which the speed of adjustment parameter was significant ($p < 0.1$) in at least one of the models estimated are presented in Table 3. The estimated average length of adjustment to 90% of long-run equilibrium values after disturbances and marketing costs of rice marketing for Liberian local rice markets is presented in Table 4.

Table 3 shows that, for the 23 market pairs for which the trace test statistics indicated cointegration, the null of no linear relationship was rejected in favour of a threshold relationship in both directions for eleven pairs and failed for six, with the remaining six indicating no long-run relationship. The estimates, displayed in Table 3, show that long-run Granger causality is mostly bidirectional, with most of the causalities associated with price changes in Red-Light, Gbarnga, Saclepea, and Buchanan.

Table 3: TVECM thresholds and long-run adjustment parameters of alternative ECM models

Granger causal direction		Threshold error correction model with three regimes (TVECM) [a]					Linear error correction model			Transmission classification [b]
		Threshold parameters		Regime adjustment parameters			Symmetric model (ECM)	Asymmetric model (AECM)		
P_1	→ P_2	L	U	L	M	U		ECM+	ECM-	
Buchanan	Saclepea [c]	-0.21	0.11	0.12	0.16	0.12	-0.17*	-0.56*	0.05	ECM-AYM
Gbarnga	Buchanan [c]	-0.17	0.13	0.17	0.12	0.12	-0.31*	-0.59*	-0.13	ECM-AYM
Gbarnga	Red-Light [c]	-0.16	0.06	0.25	0.25	0.25	-0.30*	-0.26	-0.39	ECM-SYM
Gbarnga	Voinjama [c]	-0.11	0.09	0.41	0.67*	0.41	-0.48*	-0.67*	-0.26	ECM-SYM
Gbarnga	Zwedru [c]	-0.13	0.10	0.18	0.13	0.16	-0.25*	-0.32	-0.19	ECM-SYM
Red-Light	Voinjama [c]	-0.09	0.08	0.15	0.15	0.15	-0.26*	-0.19	-0.33	ECM-SYM
Gbarnga	Tubmanburg	-0.09	0.09	0.60*	0.52*	0.52*	-0.70	-0.94	-0.48	TVECM-AYM
Tubmanburg	Gbarnga	-0.09	0.09	0.60*	0.52*	0.52*	-0.12	0.07	-0.30	TVECM-AYM
Buchanan	Tubmanburg	-0.09	0.12	0.58*	0.40*	0.40*	-0.32	-1.11	0.22	TVECM-AYM
Tubmanburg	Buchanan	-0.09	0.12	0.58*	0.40*	0.40*	0.20	0.35	0.10	TVECM-AYM
Red-Light	Tubmanburg	-0.10	0.07	0.73*	0.61*	0.61*	-0.88	-1.28	-0.31	TVECM-AYM
Tubmanburg	Red-Light	-0.10	0.07	0.73*	0.61*	0.61*	-0.15	-0.24	-0.03	TVECM-AYM
Gbarnga	Saclepea	-0.27	0.08	0.77*	0.43*	0.77*	-0.33	-0.29	-0.38	TVECM-SYM
Saclepea	Gbarnga	-0.27	0.08	0.77*	0.43*	0.77*	0.10	0.28	-0.17	TVECM-SYM
Buchanan	Red-Light	-0.10	0.13	0.40*	0.40*	0.40*	-0.14	-0.04	-0.21	TVECM-SYM
Red-Light	Buchanan	-0.10	0.13	0.40*	0.40*	0.40*	-0.53	-0.78	-0.37	TVECM-SYM
Red-Light	Saclepea	-0.21	0.07	0.38*	0.14	0.33	-0.25	-0.34	-0.12	TVECM-SYM
Saclepea	Red-Light	-0.21	0.07	0.38*	0.14	0.33	-0.02	0.12	-0.21	TVECM-SYM
Pleebo	Saclepea	-0.25	0.07	0.61*	0.58*	0.55	-0.46	-0.95	-0.17	TVECM-SYM
Saclepea	Pleebo	-0.25	0.07	0.61*	0.58*	0.55	0.18	-0.03	0.30	TVECM-SYM
Pleebo	Voinjama	-0.09	0.09	0.76*	0.76*	0.76*	-0.48	-0.87	-0.18	TVECM-SYM
Voinjama	Pleebo	-0.09	0.09	0.76*	0.76*	0.76*	0.34	-0.03	0.63	TVECM-SYM
Saclepea	Voinjama	-0.12	0.06	0.60*	0.62*	0.62*	-0.40	-0.53	-0.29	TVECM-SYM
Voinjama	Saclepea	-0.12	0.06	0.60*	0.62*	0.62*	0.21	-0.38	0.69	TVECM-SYM
Buchanan	Zwedru	-0.13	0.12	0.34	0.34	0.37*	-0.13	-0.15	-0.10	TVECM-SYM
Zwedru	Buchanan	-0.13	0.12	0.34	0.34	0.37*	0.20	0.00	0.52	TVECM-SYM
Voinjama	Zwedru	-0.07	0.06	0.46*	0.48*	0.48*	0.18	0.13	0.25	TVECM-SYM
Zwedru	Voinjama	-0.07	0.06	0.46*	0.48*	0.48*	-0.24	-0.02	-0.60	TVECM-SYM

* Significant at $p < 0.10$

[a] L, M and U denote lower, middle and upper respectively

[b] Classification-based significant ($p < 0.10$) adjustment parameters, with preference given to TVECM over ECM and AECM; and preference to AECM over ECM when TVECM is insignificant. SYM and AYM denote symmetric and asymmetric price transmission respectively.

[c] Indicates unidirectional transmission

This is reasonable, since Red-Light is the main entry port for imported rice, in addition to being located in the central part of Liberia. Gbarnga is the central market in the main rice-producing counties of Liberia (Bong, Lofa and Nimba; see Table 1). The markets influenced by both Red-Light and Gbarnga are Saclepea, Tubmanburg, Buchanan and Voinjama. In addition, Gbarnga influences prices in Zwedru and Red-Light. The price influence of Gbarnga likely reflects the impact of domestic production on the imported rice price. The only markets influencing price in Pleebo are Saclepea and Voinjama. This is counterintuitive because of the distance between these two markets and Pleebo; Voinjama is the furthest market from Pleebo. Nonetheless, it is not surprising that the price in Pleebo is not influenced by any other markets. It appears that the Pleebo price is determined independently from all other markets, consistent with the trade flows depicted in Figure 1.

Similar to Pleebo, only two markets – Saclepea and Tubmanburg – influence price in Gbarnga. This is expected, given their closeness to Gbarnga. The United Nations High Commission on Refugees established camps in Saclepea that swelled the population, food demand and, consequently, emergency delivery of rice and other staples (UNHCR 2011). Convoys of UN and Red Cross trucks and airlifts of food supplies into the Saclepea region could have created extraordinary market flows and thus influenced the price in Red-Light, Gbarnga and Pleebo. The estimates also indicate that, in the long run, policy implemented in Red-Light and Gbarnga could be transmitted to all markets except Pleebo. In 17 market pairs that are cointegrated and exhibited a long-run relationship in at least one direction, price transmission symmetry cannot be rejected in all but five. The five pairs are Buchanan-Saclepea, Gbarnga-Buchanan, Tubmanburg-Buchanan, Tubmanburg-Gbarnga and Tubmanburg-Red-Light. The results show that negative price deviations return to equilibrium faster than positive price deviations.

In Table 4, the adjustment length (incoming and outgoing) for each market pair was calculated using the significant ($p < 0.10$) adjustment parameters for both directions, where possible. Incoming and outgoing adjustment lengths were then averaged for the same market. Similarly, the trade costs for markets were calculated by exponentiating both threshold parameters (upper and lower) for specific market pairs, and then averaged for markets. The estimates in Table 4 indicate that it takes an average of 3.42 months for a 90% price adjustment, with a maximum outgoing [incoming] transmission of 4.79 [5.53] months for Red-Light [Zwedru] and a minimum outgoing [incoming] transmission of 2.04 months for Pleebo [Gbarnga]. Again, the estimates for Pleebo are counterintuitive, given the distance from its causal markets. However, it makes intuitive sense that Gbarnga has the shortest incoming transmission length because of its spatial centrality to the other markets. Also, the fact that Red-Light has the highest outgoing transmission length suggests that there may be some constraint, specifically bad road conditions, to market integration. This is explored further in the following subsection.

Table 4: Mean adjustment period length and trade costs among Liberian local rice markets

Market (P_2)	Outgoing [incoming] adjustment length (months)	Trade costs (L$/kg)	Causal markets (P_1)
Pleebo (PL)	2.04 [2.04]	1.23	SA, VO
Voinjama (VO)	2.59 [3.82]	0.82	SA, TU
Saclepea (SA)	2.81 [2.53]	0.95	BU, GB, PL, RL, VO
Tubmanburg (TU)	2.84 [2.84]	0.89	BU, GB, RL
Buchanan (BU)	3.62 [3.59]	1.02	GB, RL, TU, ZW
Gbarnga (GB)	3.90 [2.18]	0.82	GB, PL, RL, SA, ZW
Zwedru (ZW)	4.35 [5.53]	0.95	BU, GB, SA, TU
Red-Light (RL)	4.79 [4.43]	0.84	BU, GB, VO
All markets	3.42 [3.42]	0.91	All markets

Standard deviations are in parentheses

4.3 Determinants of Liberian rice market integration

The two models corresponding to equation (4) were estimated by least squares and, because of the small sample size, the coefficient standard errors were estimated using a bootstrap. The regression results are reported in Table 5. The R-squared (R^2) was 0.68 and 0.29 for the trace statistic and the average length of adjustment model respectively. In comparison with similar models from other researchers, Ismet *et al*. (1998), who use the trace statistic as their dependent variable, report an R^2 of 0.31, while the present study reports 0.68. Goletti *et al*. (1995), using the speed of adjustment as the dependent variable in one of their models, performed less well compared to this study's model (0.29 against 0.21).

Table 5: Parameter estimates of factors influencing rice market integration in Liberia

Model	Trace statistic	Length of adjustment
Distance (ln(km))	-0.318** (0.145)	0.707** (0.312)
Road (ratio) (base = 5 Mt capacity)		
Paved	-0.115 (0.271)	-0.071 (0.442)
15 Mt capacity	0.556* (0.287)	-0.013 (0.511)
Telecommunications (GSM) (base = bad)		
Good	-0.450*** (0.165)	0.876** (0.351)
Better	-0.334* (0.195)	0.714* (0.424)
Refugees (yes = 1)	0.145 (0.101)	-0.164 (0.246)
Constant	5.189*** (0.859)	-2.111 (1.619)
n	28	56
Replications	100	100
R-squared	0.676	0.287

Significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Bootstrap standard errors are in parentheses

The estimated models provide mixed evidence on the determinants of cointegration in Liberia. In Table 5 at least three variables are significant at $p < 0.10$ in each equation. Distance in both models is significant and has the expected effect. Goletti *et al*. (1995) found that distance had a negative influence on market integration. As distance increases, there likely is less cointegration. Road conditions are only significant ($p < 0.10$) for the trace statistic, but with the expected sign for 15 Mt capacity. Goletti *et al*. (1995) showed that paved road density had a positive influence on market integration. The signs on mobile communication (GSM) are counterintuitive. The communication infrastructure variable is a noisy proxy due to the lack of telephone density data for Liberia. Both Goletti *et al*. (1995) and Escobal and Cordano (2008) also found that increased communication infrastructure had a negative influence on market integration.

5. Findings and policy implications

The results indicate moderate market integration in Liberia, with 60% of all conceivable market pairs integrated and long-run causality mostly bidirectional. Given the questionable interaction of Pleebo with only two distant markets, we conclude that the price of imported rice in Pleebo is not influenced by prices in other markets. The segmentation of Pleebo, given its close proximity to Cote d'Ivoire, reflects the cross-border trade between the two countries.

The results from the asymmetric test (TVECM and AVECM) suggest the potential existence of localised market power on the seller's side, indicating some non-competitive local markets. Asymmetric price adjustments may be explained by differential seller/buyer access to market information. Local sellers may have access to superior information that allows them to pass on price changes that squeeze their margins more quickly than changes that expand margins. Buyers, on the other hand, may not have information to help them react quickly to price changes due to the large search costs (mostly transportation) they may face in an attempt to buy from alternative sources. Lastly, buyer weakness in the Liberian rice market is partly due to few staples that substitute for rice. Rice alone accounts for 40.43% (910 kcal/day) of Liberia's total daily caloric intake, while yam and cassava account for 0.58% and 16.88% respectively (FAO 2016). According to LASIP (2010), there is limited incentive to produce marketable surpluses of staples due to (1) impaired market access due to deficient road networks, (2) limited rice storage and processing infrastructure, (3) lack of appropriate market information for farmers, and (4) current rudimentary production techniques.

Because most Liberian rice markets are cointegrated to some degree, policy makers must recognise that government actions taken to affect one market – especially one of the main markets – will have impacts that transfer to other markets. Implementing a policy seeking to stabilise domestic rice supply and prices in a cost-effective way, the GoL could only intervene in Red-Light and Gbarnga. Over time, the actions implemented would be transmitted to all markets except Pleebo. While only one road quality variable was statistically significant in influencing the level of market integration, distance between markets had the expected effect on the integration level. This suggests that steps to lower transportation costs – likely by better roads – would improve market integration. In addition, our findings indicate that integrating rural markets with urban markets would be enhanced by rehabilitating and expanding Liberia's transportation infrastructure.

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