Price Discovery in the U.S. Milled Rice Markets using a Cluster Analysis and Tournament

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Abstract

A major aspect concerning US rice producers and milling industry has to do with price transmission and the price discovery process among domestic milled rice markets and the international rice market. The paper investigates the dynamic relationships between the US domestic and international rice prices and determines the price discovery process using the vector error correction model (ECM) and the tournament approach using a cluster analysis. Results determine that Arkansas medium grain and California short grain are milled rice price reference or leaders in the U.S. We compare the speed of adjustment coefficients from ECM and find that California short grain has a slight edge over Arkansas medium though this lead may be rather insignificant. Two markets contribute equally in the price discovery process. We test both Arkansas medium and California short against Thai 5% rice export price, a frequent reference of international rice price. Result indicates that Thai 5% slightly leads Arkansas medium but is mildly led by California short. The US market and Thai 5% contribute equally in the price discovery in the international market. Results indicate differences from prior findings that the US rice market is segregated from Asian/international market.

Keywords: Cluster analysis, Price discovery, Rice market, Vector error correction

JEL Code: Q11, Q13, C32

Introduction

Rice is a staple commodity in the U.S. and world markets, especially in Southeast Asian countries, Africa and Latin America. Giraud (2013) emphasizes that rice consumption accounts for 20% of the caloric intake of the world population. There are three varieties of rice classified according to the length of grain such as long, medium and short grain. Long grain rice is firm and dry when cooked. It is often used to make pilaf[1] or is served plain as a side dish. Medium grain rice is sweeter than long grain and may be used in making Italian risotto. Short grain rice is the stickiest of the three and may be used in sushi and to make rice pudding. Rice cultivation is labor intensive, and requires heavy rainfall or extensive irrigation. It is unsurprising, therefore, that much of the world's production occurs in Asia, with Thailand being the world's largest producer.

US rice is produced in four distinct regions, i.e. Arkansas, Mississippi Delta, Southeast Texas-Louisiana, and northern California (Sacrament Valley). Rice is among the top seven US crops in terms of harvested acres and sixth in terms of cash receipts (sales) (ERS - USDA). Long grain is almost entirely produced in the southern regions, encompassing about 70% of US rice production. Medium grain is produced in Arkansas and California, and accounts for over 25% of US rice production, while the remaining less than 2% of production is short grain grown in California (Childs, 2012).

Rice exports are a very significant market for U.S. rice producers and milling industry given that the U.S. exports about half of its rice production, mostly to Mexico, Central America, Northeast Asia, the Caribbean, and the Middle East. In 2015, about 50 percent of all U.S. rice

[1] Dish of spiced rice, often with chopped vegetables, fish, or meat added.

export went to Mexico and Central America. About 50% of rice exports is in the milled form (Rice Yearbook 2015, Tables 12 and 13). The U.S. is considered as a major rice exporter, accounting for over ten percent of the annual volume of global rice trade (ERS: Rice Yearbook). International trade agreements during the 1990's led to substantial growth in the exports of US rice, specifically the 1994 Uruguay Round Agreement of the World Trade Organization (WTO) as well as the North American Free Trade Agreement (NAFTA). Currently Mexico is the US largest rice importer, followed by Japan and Haiti. In the international markets, US rice competes mainly with Asian producers, especially with rice from Thailand (Childs, 2012).

A major aspect concerning the US rice producers and milling industry has to do with price transmission and the price discovery process among the domestic markets and the international market. Despite the relevancy of the matter, the literature addressing the relationship among the US and international rice markets is rather thin.[2] Taylor et al. (1996) investigate the dynamic relationships between US and Thai rice prices by considering a US (transportation-adjusted) cash rough rice price from Texas, a Thai milled rice price, a rough rice futures prices and a USDA estimated world market price. They apply an error correction model and find that the estimated USDA world rice market price behaves somewhat exogenously; however, the other three prices are co-integrated. Thus the US cash rough rice from Texas, the Thai milled rice and the rough rice futures market have long term dynamic relationships among them. The criteria for selecting the specific cash US rice price is not given. Other recent studies have addressed the transmission of world rice prices to local markets.

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[2] Studies regarding Asian markets about asymmetric price transmission and/or dynamic interrelationships among rice prices are abundant, for example, Alexander and Wyeth (1994), Silvapulle and Jayasuriya (1994), Ghoshary (2008), Minot (2011), Alam et al. (2012), Jamora and von Carmon-Taubadel (2012), Suryaningrum, Chang, and Anindita (2013), and Gedaraa, Ratnasiria, and Bandara (2016) among others.

Kim, Tejeda, and Yu (2016) investigate whether US milled rice markets are spatially integrated across production regions and rice varieties using a vector error correction model. They find that Arkansas-Missouri long grain is a reference price in long grain markets and Arkansas-Missouri medium grain is also a leading price in medium grain market. Interestingly, they also find that Arkansas-Missouri medium grain plays an important role in long grain markets, too.

This study investigates the dynamic relationships between the US domestic milled rice markets and international rice price and determines the price discovery process, which provides the lead-lag relationships in the market. In doing so, we identify the reference US rice price among the seven different milled rice markets, and also determine whether the US rice market is integrated with the international market. We examine the potential presence of asymmetric adjustment in the price discovery (transmission) process; i.e., price transmission from/to US rice market from/to world rice market. We seek to determine if the US rice price has an effect on the international market price or vice-versa. Jamora and von Carmon-Taubadel (2012) find that the US markets are segregated from Asian/international markets, especially Thailand rice price.

We apply a vector error correction model (ECM) to study the dynamic relationships among rice prices. In addition, to determine the price discovery process between markets, we apply a technique developed by Gonzalo and Granger (1995) and expanded in Theissen (2002). The technique is a function of the relative ratio of the speed of adjustments of co-integrated series in the ECM. This method has been used by Schwarz and Szakmary (1994), Foster (1996), Theissen (2002), Eun and Sabherwal (2003), Thurlin (2009), Figuerola-Ferretti and Gonzalo (2010), Plato and Hoffman (2011), Kim (2011), and Arnade and Hoffman (2015). However, the technique has only been applicable for the case of bivariate series; i.e., allowing for one cointegration vector. Thus it is not applicable to the multivariable case that may have multiple cointegrating vectors (Kim, 2011). Our study suggests a novel way to overcome this problem by using a *cluster analysis* (Tan, Steinbach, and Kumar, 2006), which considers a partition of data according to meaningful and/or useful characteristics. After this data partition using the cluster analysis, we apply the tournament approach, a series of bivariate ECM estimation and determine price discovery. In doing so, we provide insights in the price discovery process among multiple US milled rice markets, and the potential link it has with international markets. Relevant findings regarding risk management effects for producers, as well as having policy implications are provided.

Methods

The term, price discovery, refers to a process whereby the relative contributions of interrelated submarkets to the overall market price can be determined. The submarket with the larger contribution is called the "price discovery." The theoretic groundwork to this approach was laid by Gonzalo and Granger (1995). The techniques introduced in Gonzalo and Granger (1995) were further refined in Theissen (2002). A (bivariate) ECM model permits the estimation of the absolute (speed of) adjustment rates of the co-integrated series, which are related to market efficiency. As Arnade and Hoffman (2015) note, if price information transmits fully across markets, then prices should quickly converge to the long-run equilibrium. Let p_t be a 2×1 price vector with an ECM representation being expressed in the following form:

$$(1) \qquad \Delta p_t = \alpha(\beta' p_{t-1} - c) + \sum_{k=1}^{K-1} \Gamma_k \Delta p_{t-k} + e_t,$$

where α is 2×1 vector of adjustment coefficient, β is 2×1 cointegrating vector and c is an intercept. K is the lag-length of the vector autoregression (VAR) and e_t is the reduced-form shock. Following Gonzalo and Granger (1995), the relative ratio of the adjustment coefficients is defined by

$$(2) \qquad \theta_1 = \frac{|\alpha_2|}{|\alpha_1| + |\alpha_2|}, \quad \theta_2 = \frac{|\alpha_1|}{|\alpha_1| + |\alpha_2|}, \text{ and } \theta_1 + \theta_2 = 1$$

A high (low) θ_i indicates a low (high) α_i, which in turn implies that market i slowly (quickly) responds to an unpredicted shock in the system; therefore market i is (not) the price discovery reference market. If $\theta_1 = \theta_2 = 0.5$, both markets contribute equally to the price discovery process; i.e. both markets move at similar rate towards the long-run equilibrium.

As mentioned, when there are multiple markets, this technique may not be applicable. According to Kim (2011), we may arrange price discovery according to the relative magnitude of α_i for multivariate cases with one cointegrating relation, but it is not clear on how to calculate θ_i (Kim, 2011, pp. 50-51). In addition there may be more than one cointegrating relation for the multivariate case. The tournament approach using the cluster analysis method provides a way to overcome this limitation. The cluster analysis method divides rice price data into groups (clusters) that are meaningful, useful or both (Tan, Steinbach, and Kumar, 2006). It implements a hierarchy using various techniques, for example, pairwise distance between all data points. Once the cluster analysis provides the resulting cluster(s), a sequential ECM approach is applied like a tournament, and we can identify the price discovery region(s) for each hierarchy accordingly.

In this study rice prices are clustered based on pairwise distance between sample data, which is determined by

$$(3) \qquad d(p_1, p_2) = \sqrt{\sum_{i=1}^{n} (p_{1i} - p_{2i})^2} \ ,$$

where p_1 and p_2 are a pair of price data. If the distance between p_1 and p_2 is smaller than the distance between p_1 and p_3, then p_1 is more similar to p_2 than to p_3. We apply equation (3) to all possible pairs of price series. Once each price is assigned to its own cluster, then each of the distances between clusters are recomputed (Muller, 2013). Clustering is used to identify structure among the data, organizing data into homogeneous groups where the within-group-object similarity (or dissimilarity) is minimized (Warren Liao, 2005).

Data

For the U.S. markets we consider average monthly f.o.b. prices in $/cwt from major milling centers located in each specific region. In particular, we use price data for long, medium and short grain milled rice from Arkansas and Missouri, Louisiana and Mississippi, Texas and California, that is, Arkansas long (`ar_lng`), Arkansas medium (`ar_med`), Louisiana long (`la_lng`), Louisiana medium (`la_med`), Texas long (`tx_lng`), California medium (`ca_med`) and California short (`ca_sht`) obtained from the Agricultural Markets Service – USDA (Table 17, www.ers.usda.gov/data-products/rice-yearbook-2015.aspx). Thai 5% price (`thai_5`) is used as the reference world price (Jamora and von Cramon-Taubadel, 2012), and is obtained from the Commodity Price Data of the World Bank (http://data.worldbank.org/data-catalog/commodity-price-data). Prices range from August 1979 to February 2015 and illustrated in Figure 1. The spike in prices between 2008 and 2010 is related to global rice price movements over the same period (Childs and Kiawu, 2009). After 2010, California short grain is generally the most expensive and long grains from Arkansas, Texas, and Louisiana are lower than the short grain and medium rice varieties. Descriptive statistics of the data are reported in Table 1.

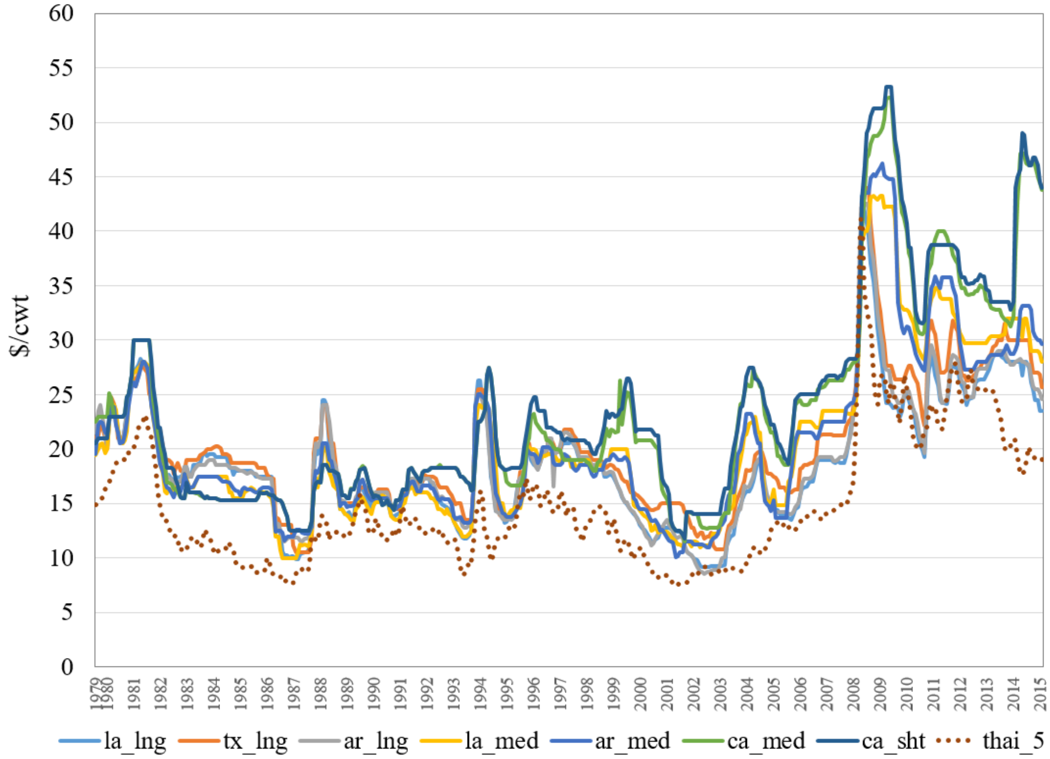

Figure 1: U.S. (Milled) Rice Prices of Grain Size & Major Producing States and Thai 5%
Source: Table 17, Rice Yearbook 2015, Agricultural Markets Service – USDA and Commodity price data of World Bank.
Note: ar_lng = AR-MO long grain, la_lng = LA-MS long grain, tx_lng = Texas long grain, ar_med = AR-MO medium grain, la_med = LA-MS medium grain, ca_med = CA medium grain, ca_sht = CA short grain, and thai_5 = Thai 5% exporting price

Table 1. Descriptive Statistics of Data ($/cwt), August 1979 – February 2015

	Variables	Mean	Std. Dev	CV	Min	Max	Autocorr.
Arkansas long grain	ar_lng	19.06	5.94	31.17	8.56	42.50	0.983
Louisiana long grain	la_lng	18.74	5.82	31.03	9.13	43.25	0.982
Texas long grain	tx_lng	20.11	5.96	29.62	10.50	44.00	0.982
Arkansas medium grain	ar_med	20.44	7.71	37.73	10.06	46.25	0.990
Louisiana medium grain	la_med	20.28	7.64	37.67	10.00	43.25	0.992
California medium grain	ca_med	23.09	9.44	40.89	11.50	52.25	0.993
California short grain	ca_sht	23.66	9.68	40.93	11.81	53.25	0.993
Thailand 5%	thai_5	14.68	5.79	39.45	7.43	41.14	0.981

Source: Table 17, Rice Yearbook 2015, Agricultural Markets Service – USDA and Commodity price data of World Bank.
Note: ar_lng = AR-MO long grain, la_lng = LA-MS long grain, tx_lng = Texas long grain, ar_med = AR-MO medium grain, la_med = LA-MS medium grain, ca_med = CA medium grain, ca_sht = CA short grain, and thai_5 = Thai 5% exporting price

Results

First, the data series are tested for non-stationarity using the Augmented Dickey-Fuller (ADF) test (Dickey and Fuller, 1981) considering a constant. In addition, the Phillips Perron test (Phillips and Perron, 1988) was applied to corroborate results. For the ADF test, the optimal lag length for the augmented terms was determined by minimizing the Schwarz-loss statistics (SL in Table 2). A unit root was found in most of rice price series based on the ADF test. The Phillips Perron tests determined that all series are non-stationary (Table 2).

Table 2: Unit Root Test Results

Raw data	ADF test for unit root (non-zero mean)							
	ar_lng	ar_med	ca_med	ca_sht	la_lng	la_med	tx_lng	thai_5
Test statistics	-3.08	-2.50	-1.53	-1.54	-3.38	-2.41	-3.15	-2.05
Lags (per SL)	1	1	1	1	1	1	1	2
5% Crit. value	-2.86	-2.86	-2.86	-2.86	-2.86	-2.86	-2.86	-2.86
Decision[a]	S	NS	NS	NS	S	NS	S	NS
	Phillips Perron test for unit root (non-zero mean)							
	ar_lng	ar_med	ca_med	ca_sht	la_lng	la_med	tx_lng	thai_5
Z(t) stat	-2.63	-2.15	-1.46	-1.38	-2.79	-2.09	-2.73	-2.38
Lags[b]	5	5	5	5	5	5	5	5
5% Crit. value	-2.87	-2.87	-2.87	-2.87	-2.87	-2.87	-2.87	-2.87
Decision	NS	NS	NS	NS	NS	NS	NS	NS

[a] NS = non-stationary, S = stationary; [b] The number of Newey-West lags $\{4(T/100)^{\frac{2}{9}}\}$ lags

Note: ar_lng = AR-MO long grain, la_lng = LA-MS long grain, tx_lng = Texas long grain, ar_med = AR-MO medium grain, la_med = LA-MS medium grain, ca_med = CA medium grain, ca_sht = CA short grain, and thai_5 = Thai 5% exporting price.

First differenced data are all stationary (test results are not reported here) and thus all the price series are I(1).

We proceed to apply the cluster analysis method to our seven US market series and Thailand 5% rice prices. An illustration of the resulting cluster dendrogram is shown in Figure 2. In Figure 2, prices are joined by short branches if they are similar to each other, and by increasingly longer branches as their similarity decreases. We find that the first round of pairwise tournament testing is to be held by: California medium and California short, by Louisiana medium and Arizona medium, and by Louisiana long and Arizona long (Figure 2). Thus Texas long is left for the next stage and to be compared with the "leader" or reference selected among Louisiana long and Arizona long.

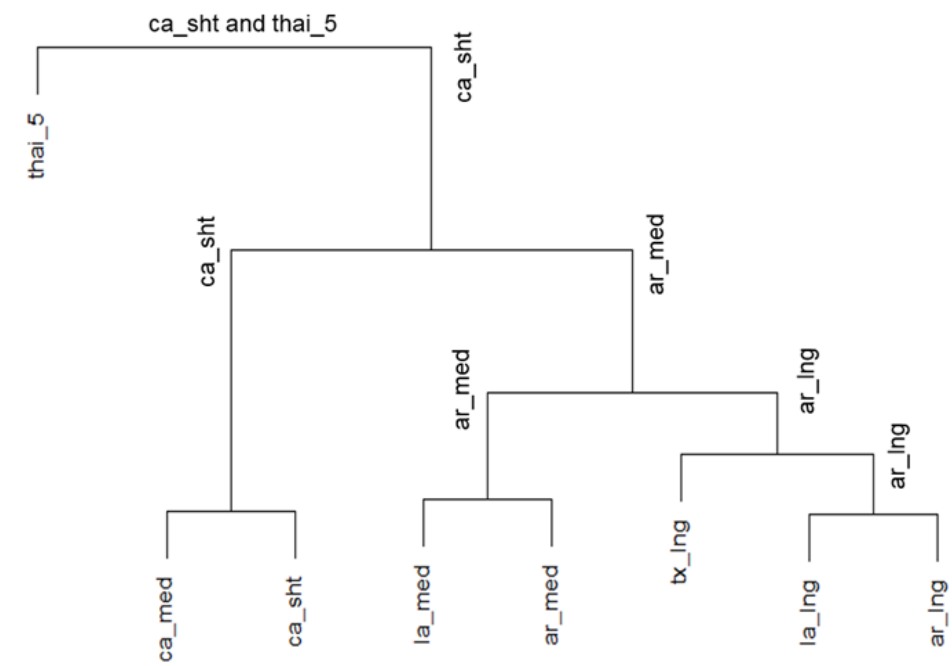

Figure 2: Cluster Dendrogram and Price Discovery

ar_lng = AR-MO long grain, la_lng = LA-MS long grain, tx_lng = Texas long grain, ar_med = AR-MO medium grain, la_med = LA-MS medium grain, ca_med = CA medium grain, ca_sht = CA short grain, and thai_5 = Thai 5% exporting price

Results from analyzing the first round of bivariate markets are provided in Table 3. The Johansen's trace test in Table 3a identifies a significant co-integrating vector for each pair of milled rice markets studied. Moreover, after estimating the bivariate ECM model among the markets, results for each variable's adjustment coefficients (α_i) as well as their relative adjustment coefficient (θ_i), is presented in Table 3b. From these outcomes, we find that

California medium adjusts faster than California short grain to unpredicted shocks in these markets and thus California short (ca_sht) is the leader among the two. In regards to the medium grain markets of Arkansas and Louisiana (ar_med and la_med), it is Arkansas with a minor lead over Louisiana, given that the latter responds a bit quicker to market shocks. Finally, among the long grain markets of Arkansas and Louisiana, here it is clearly Arkansas as the leader among the two markets.

Table 3a. Johansen's Trace Tests – First Round Cointegration

Price pair	Rank	LR	P value	95%	99%	Decision[a]
ca_med vs ca_sht	0	29.59	0.001	20.16	24.69	R
	1	2.72	0.639	9.14	12.53	FR
ar_med vs la_med	0	39.76	0.000	20.16	24.69	R
	1	6.63	0.152	9.14	12.53	FR
ar_lng vs la_lng[b]	0	49.11	0.000	20.16	24.69	R
	1	10.35	0.029	9.14	12.53	FR

Note: The optimal endogenous lags are determined based on Schwarz Criterion (not reported).

ar_lng = AR-MO long grain, la_lng = LA-MS long grain, ar_med = AR-MO medium grain, la_med = LA-MS medium grain, ca_med = CA medium grain, and ca_sht = CA short grain

[a] Decision: R – reject, FR = fail to reject

[b] ar_lng vs la_lng H0: Rank = 1 is rejected at 5% significance level. We use 1% level.

Table 3b. First Round Adjustment and Relative Adjustment Coefficients

Price pair	α_1	α_2	θ_1	θ_2
ca_med vs **ca_sht**	-0.113** (0.053)	0.020 (0.052)	0.15	**0.85**
ar_med vs la_med	-0.064 (0.039)	0.084** (0.039)	**0.57**	0.43
ar_lng vs la_lng	0.002 (0.056)	0.196*** (0.056)	**0.99**	0.01

ar_lng = AR-MO long grain, la_lng = LA-MS long grain, ar_med = AR-MO medium grain, la_med = LA-MS medium grain, ca_med = CA medium grain, and ca_sht = CA short grain

Numbers in parentheses are stand deviation and superscripts ***, **, * denote statistical significance at the 1%, 5%, and 10% level, respectively.

A high θ means low α and the market doesn't respond to the unpredicted shock in the market. It implies the market with a higher θ value is the price discovery. Winners of the tournament, i.e., price discovery is indicated in bold font.

The second round consists of Texas long grain versus Arkansas long grain and results are provided in Tables 4a and 4b. From Table 4a, we observe that one co-integration vector is significantly determined among the two series. Moreover, Table 4b indicates that Arkansas long is the leader with respect to Texas long grain. The third round consists of Arkansas long and Arkansas medium with results also in Tables 4a and 4b. Once again there is significant evidence supporting the existence of one cointegrating vector among the two markets. Analyzing the relative adjustment coefficients for this third round in Table 4b, shows that Arkansas medium leads Arkansas long. The next pairing in round four, and final considering US production, is therefore between Arkansas medium and California short. Results also show evidence of the two markets being co-integrated.

Table 4a. Johansen's Trace Tests – Second, Third and Fourth Rounds Cointegration

Price pair	Rank	LR	P value	95%	99%	Decision[a]
			Second round			
ar_lng vs tx_lng[b]	0	32.93	0.000	20.16	24.69	R
	1	10.84	0.023	9.14	12.53	FR
			Third round			
ar_lng vs ar_med	0	23.72	0.014	20.16	24.69	R
	1	6.08	0.191	9.14	12.53	FR
			Fourth round			
ar_lng vs la_lng	0	24.27	0.012	20.16	24.69	R
	1	3.08	0.576	9.14	12.53	FR

The optimal endogenous lags are determined based on Schwarz Criterion (not reported).

ar_lng = AR-MO long grain, tx_lng = Texas long grain, ar_med = AR-MO medium grain, la_lng = LA-MS long, and ca_sht = CA short grain

[a] Decision: R – reject, FR = fail to reject

[b] ar_lng vs tx_lng H0: Rank = 1 is rejected at 5% significance level. We use 1% level.

Table 4b. Second, Third and Fourth Rounds Adjustment and Relative Adjustment Coefficients

Price pair	α_1	α_2	θ_1	θ_2
	Second round			
ar_lng vs tx_lng	0.052^{*} (0.030)	0.121^{***} (0.028)	**0.70**	0.30
	Third round			
ar_lng vs **ar_med**	-0.058^{***} (0.017)	-0.005 (0.016)	0.08	**0.92**
	Fourth round			
ar_med vs **ca_sht**	-0.043^{***} (0.017)	0.036^{***} (0.014)	0.46	**0.54**

ar_lng = AR-MO long grain, tx_lng = Texas long grain, ar_med = AR-MO medium grain, la_lng = LA-MS long, and ca_sht = CA short grain

Numbers in parentheses are stand deviation and superscripts ***, **, * denote statistical significance at the 1%, 5%, and 10% level, respectively.

A high θ means low α and the market doesn't respond to the unpredicted shock in the market. It implies the market with a higher θ value is the price discovery. Winners of the tournament, i.e., price discovery is indicated in bold font.

In addition, when comparing the relative adjustment coefficients among these two markets, it is California short that seems to have a slight edge over Arkansas medium, though this lead may be rather insignificant. (Figure 4b, fourth round). In effect this indicates that these two markets move together to unpredicted shock in the market, i.e., both markets contribute roughly equally to the price discovery process. Given that there's no significant market leader between California short and Arkansas medium, we test each one against Thai 5%. Results are in Tables 5a and 5b. One co-integration vector is found in each pair of tested markets, as seen in from Table 5a. In regards to the price leader between California short and Thai 5%, it is California short grain that leads, though not significantly as by less than ten percentage points. However, when comparing Thai 5% and Arkansas medium, it is Thai 5% as the price leader. This result may be anticipated given that round four between Arkansas medium and California short arrives at California short having a mild lead. Thus Thai 5% leads Arkansas medium, but is mildly lead by California short. Again it implies that the US market and Thai 5% contribute roughly equally to the (international) price discovery process. It is noteworthy that the result is different from Jamora and von Cramon-Taubadel (2012). They find no cointegration between US long and Thai 5%, and US medium and Thai 5%. Either case we conclude that there is no asymmetric price transmission between the US reference rice price, i.e., Arkansas medium and/or California short and the world rice price, i.e., Thai 5%.

Table 5a. Johansen's Trace Tests – Final Round Cointegration

Price pair	Rank	LR	P value	95%	99%	Decision
ca_sht vs thai_5	0	21.41	0.033	20.16	24.69	R
	1	2.22	0.734	9.14	12.53	FR
ar_med vs thai_5	0	29.65	0.001	20.16	24.69	R
	1	4.50	0.354	9.14	12.53	FR

The optimal endogenous lags are determined based on Schwarz Criterion (not reported).
ar_med = AR-MO medium grain, ca_sht = CA short grain, and thai_5 = Thailand 5% rice exporting price

Table 5b. Final Round Adjustment and Relative Adjustment Coefficients

Price pair	α_1	α_2	θ_1	θ_2
ca_sht vs thai_5	-0.027^{***} (0.008)	0.031^{***} (0.012)	**0.53**	0.47
ar_med vs **thai_5**	-0.046^{***} (0.016)	0.036^{**} (0.016)	0.44	**0.56**

ar_med = AR-MO medium grain, ca_sht = CA short grain, and thai_5 = Thailand 5% rice exporting price
Numbers in parentheses are stand deviation and superscripts ***, **, * denote statistical significance at the 1%, 5%, and 10% level, respectively.
A high θ means low α and the market doesn't respond to the unpredicted shock in the market. It implies the market with a higher θ value is the price discovery. Winner of the tournament, i.e., price discovery is indicated in bold font.

Summary and Concluding Remarks

A major aspect concerning the U.S. rice producers and milling industry has to do with price transmission and the price discovery process among these markets. Despite the relevancy of the matter, the literature addressing the relationship among the US and international rice markets is rather thin. The paper investigates the dynamic relationships between the US domestic and international rice prices, and determines the price discovery process, which provides the lead-lag relationships among prices in the markets. In doing so, we identify the reference US rice price among seven different (milled rice) markets, and also identify whether the US rice market is integrated with the international market. We also examine the potential presence of asymmetric adjustment in the price discovery (transmission) process; i.e., price transmission from/to US rice market from/to world rice market.

Results show that the first round of pairwise tournament testing is to be held by: i) California medium and California short, ii) Louisiana medium and Arizona medium, and iii) Louisiana long and Arizona long. Thus Texas long is left for the next stage and to be compared with the “leader” selected among Louisiana long and Arizona long (Figure 2). From the series of ECM estimations and computing relative adjustment coefficients (Tables 3 and 4), Arkansas medium and California short are identified as (milled rice) price leaders in the U.S. This is similar to conclusions from Kim, Tejeda and Yu (2016) who perform a multivariate time series analysis. When comparing the relative adjustment coefficients among these two co-integrated markets, California short obtains a slight edge over Arkansas medium, though this lead may be rather insignificant. Two markets move together to unpredicted shock in the market, i.e., both markets contribute roughly equally to the price discovery process.

Given that there’s no significant market leader between California short and Arkansas medium, we test both California short and Arkansas medium against Thai 5% rice export price. Results indicate that Thai 5% leads Arkansas medium, but is mildly led by California short. This implies that the US rice market and Thai 5% contribute roughly equally to the (international) price discovery process. Also this is different from prior findings that the US market is segregated from Asian/international markets.

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