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Threshold Effects on Procurement Price Relationships for Fed Cattle and Hogs

Yoonsuk Lee

Aquaculture/Fisheries Center
University of Arkansas at Pine Bluff
Pine Bluff, AR 71601
Phone: 870-575-9809
Fax: 807-575-4637
Email: keynes833@hotmail.com

Clement E. Ward

Department of Agricultural Economics
Oklahoma State University
Stillwater, OK 74075
Phone: 405-774-9821
Fax: 405-774-8210
Email: clement.ward@okstate.edu

Mallory Vestal

Department of Agricultural Business & Economics
West Texas A&M University
Canyon, TX 79016
Phone: 806-651-2718
Email: mvestal@wtamu.edu

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Introduction

The importance of the cash market on price discovery in livestock procurement by packers has been a major concern to many in the beef and pork industries for over three decades (Lawrence 2010; Ward 2010). The cash market for both fed cattle and hogs has thinned sharply in recent years. This has raised questions and concerns how the recent trend in negotiated cash market affects price discovery, especially when many contract prices are tied to the negotiated cash market. The stable long-run relationship between cash prices and alternative marketing arrangement (AMA) prices must adjust to these changes. Lee, Ward, and Brorsen (2012) confirmed the importance of cash prices in price discovery for fed cattle and hogs, using a traditional cointegration test for integrated AMA prices, and determined Granger causal direction between cash prices and other procurement prices based on a stable long-run equilibrium model. Given the sharp decline in negotiated cash pricing, they also examined the data in three-year subperiods and found cointegration and causality had changed over time.

Relationships between economic variables often display nonlinear behavior, characterized by the presence of threshold variables such as policy and transaction cost changes. Threshold cointegration allows the linear and stable relationship based on the conventional cointegration to adjust if a series displays different behavior beyond a threshold (Sephton 2003). In this study, we adapt the threshold cointegration models for discontinuous adjustment to a long-run equilibrium between negotiated cash prices and other procurement prices due to a sudden change to cash prices in recent years. The role of cash prices in price discovery for fed cattle and hogs is analyzed for the potential presence of multiple equilibria.

The overall objective of this study is to determine the threshold effects of cointegrated procurement prices and identify the changes in the relationship between cash market prices and AMA prices for fed cattle and slaughter hogs with respect to potential multiple equilibria. Specific objectives of this study are to: 1) determine nonlinear behavior by weighted portmanteau tests and then detect the potential number of thresholds via Hansen's (1999) test in cointegrating residuals between negotiated cash prices and each AMA price for fed cattle and hogs; 2) Based on the finding of thresholds, estimate a threshold cointegration in a vector error correction model, using a Lagrange Multiplier (LM) test statistic proposed by Hansen and Seo's (2002); and 3) describe Granger causal relationships between cash prices and AMA prices in terms of threshold effects to specify the role of cash market prices in price discovery.

Data

Data used in this study are collected from mandatory price reports at the Agricultural Marketing Service (AMS) Market News site for livestock reports (<http://www.ams.usda.gov/AMSV1.0/LPSMarketNewsPage>). Weekly data used in this paper start from May 2001 through April 2013. This represents three more years of data than that by Lee, Ward, and Brorsen (2012). For this study, AMAs are categorized into four classes for fed cattle: negotiated cash trades, forward contracts (mostly basis contracts), formula arrangements (mostly marketing/purchasing agreements with price tied to the cash market), and negotiated grid trades. For slaughter hogs, AMAs are categorized into four classes; negotiated cash trades, swine market formula arrangements (usually marketing contracts with price tied to the cash market), other market formula arrangements (with price often tied to the futures market), and other purchase

methods (which may be production contracts with price tied to cost of production or with price window clauses).

Procedure

Our procedure determines whether the effects of thresholds can change the role of negotiated cash prices on price discovery for fed cattle and hogs. First, cointegration tests are performed in each three-year subperiod to see the relationship between negotiated cash prices and other AMA prices over time. Rather than jumping to the estimation of Hansen and Seo's (2002) thresholds effects on vector error correction models, we first attempt to confirm the presence of nonlinearity in a cointegrating residual of the bivariate pairing of negotiated cash prices and other AMA prices: for fed cattle, 1) negotiated cash and forward contract prices, 2) negotiated cash and negotiated grid prices, and 3) negotiated cash and formula prices; and for hogs, 4) negotiated cash and swine market formula prices, 5) negotiated cash and other market formula prices, and 6) negotiated cash and other purchase prices. Then we determine the potential number of thresholds in a cointegrating residual via Hansen's (1999) approach. Based on the number of thresholds, this paper estimates the effects of threshold on vector error correction models through Hansen and Seo's (2002) tests. Lastly, Granger causality tests, depending on a discrete adjustment to a long-run relationship, are conducted for each bivariate pair of negotiated cash prices and other AMA prices.

Methodology

Test for Nonlinear Behavior

The linear approximation of time-series variables is a useful assumption for a time-series estimation process, but ignoring nonlinear behavior of a time series can result in incorrect information based on the empirical results. This paper pretests the presence of nonlinearity in cointegrating residuals for each pair of negotiated cash prices and other AMA prices for fed cattle and hogs, using the weighted portmanteau tests. Since a portmanteau test does not require an alternative hypothesis to be fully specified, portmanteau tests in this paper indicate a broad test of nonlinearity. The weighted Ljung-Box and Monti statistics improved by Fisher and Gallagher (2012) are adapted to test nonlinearity in cointegrating residuals. The weighted tests concentrate on the first autocorrelation calculated from all observations to obtain statistically accurate estimator (Fisher 2012). Under the null hypothesis of a linear autoregressive model in a cointegrating residual, weighted Ljung-Box and Monti statistics asymptotically follow a chi-square distribution with $m - (p + q)$ degrees of freedom, where m is lags, and p and q are the order of autoregressive and moving average terms, respectively.

Tests for Self-Exciting Threshold Autoregressive Specification

Based on the nonlinearity in cointegrating residuals, the possible number of thresholds causing nonlinearity is detected using Hansen's (1999) approach. In order to avoid imposing a fixed number of thresholds, this study applies Hansen's test in cointegrating residuals between negotiated cash prices and other AMA prices to determine the number of thresholds. Hansen (1999) applied the least square method to test non-linearity in the context of self-exciting threshold autoregressive (SETAR) models, assuming that the behavior of the series changes once

the series enters a different regime. His approach provides an explicit method to determine the number of thresholds, through a test of one-regime, two-regimes, and three-regimes based on the given order of autoregressive terms where the i th number of thresholds imply $(i + 1)$ th regimes.

Threshold in Cointegration and Vector Error Correction Model

Balke and Fomby (1997) proposed a threshold cointegration that reflects discontinuous adjustment to a long-run equilibrium, using a threshold autoregression in a univariate cointegrating residual. Such single-equation search process of threshold cointegration is potentially misspecified (Sephton 2003). In this paper, we adapt Hansen and Seo's test to estimate threshold effects on a set of bivariate price series. This paper, however, conducts several pretests before applying Hansen and Seo's threshold cointegration test. Since Hansen and Seo's threshold cointegration test was proposed for the two-regime case with one cointegrating vector, it can mislead the threshold effects from an error correction model when there exist more than two regimes.

The presence of thresholds in cointegrated variables of negotiated cash prices and AMA prices cause unstable long-run relationships according to the magnitude of a threshold variable. The standard method of cointegration between negotiated cash prices and other AMA prices is to determine a stationary relationship of nonstationary AMA prices and use a corresponding error correction model to estimate the speed of adjustment to a linear long-run equilibrium. However, threshold cointegration allows a non-linear adjustment to occur after the deviation exceeds some critical threshold, thus possibly taking into account stickiness between pricing methods for both fed cattle and hogs. Threshold cointegration suggests that the dynamic behavior of negotiated cash prices and other AMA prices changes in response to thresholds. Granger and Lee (1989)

adjusted the threshold effects for only the vector error correction term. However, Hansen and Seo (2002) expanded threshold effects to the error correction term as well as to the intercept and lags terms.

Granger Causality Test According to Threshold Vector Error Correction Model

It is essential to decide the direction of causality between two related variables and also whether or not feedback is occurring (Granger 1969). Since Granger causality can be carried out in several ways, Lee, Ward, and Brorsen (2012) used a Granger causality test for bivariate cointegrated series in terms of a vector error correction (VEC) model with (p) lags, using the full information maximum likelihood method. In this paper, we adapt their approach to determine the causal direction between negotiated cash prices and other AMA prices for fed cattle and hogs based on the vector error correction models with threshold effects.

Results

This study deliberately divides a full 12 years of data into 3-year intervals; (subperiod 1 is from May 2001 to April 2004, subperiod 2 is from May 2004 through April 2007, subperiod 3 is from May 2007 to April 2010, and subperiod 4 is from 2010 to April 2013), to examine whether cointegration has changed over time. The cointegration results from subperiods imply that there might exist multiple equilibria in each pair of negotiated cash price and other AMA prices for both fed cattle and hogs. Tables 1 and 2 display the results of Johansen's cointegration tests for fed cattle and hogs by subperiod. Johansen's test is conducted by the trace test that estimates a null hypothesis of r cointegrating vectors against the alternative hypothesis of n cointegrating vectors, $r = 0, 1, \dots, n-1$; and the maximum eigenvalue test that determines the null

hypothesis of r cointegrating vectors against the alternative hypothesis of $r + 1$ cointegrating vectors. The cointegration tests in each pair of negotiated cash and other AMA prices are not consistent for each subperiod.

Table 3 reports the results of nonlinear behavior in each cointegrating residual between negotiated cash prices and other AMA prices for both fed cattle and hogs. The weighted Ljung-Box and Monti statistics are compared with an asymptotic chi-square distribution, $\chi_{0.95}^2 = 18.49$. All cointegrating residuals reject the null hypothesis of linearly fitted models. For both fed cattle and hogs, such results suggest there exist nonlinear behavior in a cointegrating residual of negotiated cash prices and other AMA prices. However, the weighted Ljung-Box and Monti tests do not tell us the explicit cause of nonlinearity.

Based on results of the weighted portmanteau tests, we determine the number of thresholds in each cointegrating residual, using Hansen's test. Table 4 shows the number of thresholds in SETAR models. For fed cattle, we found one threshold (two regimes) in cointegrating residuals between negotiated cash prices and forward contract prices, and between negotiated cash prices and formula prices, respectively. In the pair of negotiated cash prices and negotiated grid prices, we cannot find any threshold and a linear autoregressive model fits the series better than threshold autoregressive models. For hogs, there exist no thresholds in cointegrating residuals for all pairs of negotiated cash prices and other AMA prices. No threshold effect of cointegration implies the long-run relationship between negotiated cash prices and swine market formula prices, between negotiated cash prices and other market formula prices, and between negotiated cash prices and other purchase prices are linear and stable. For some pairs of negotiated cash prices and other AMA prices in fed cattle and hogs, conventional cointegration models may be preferred to threshold cointegration models.

Granger causality between negotiated cash prices and other AMA prices are tested to reveal the role of negotiated cash prices with the threshold vector error correction models. For fed cattle, there are two regimes in the pair of negotiated cash prices and forward contract prices and four lags are selected for TVEC model specification in each regime. In regime 1 from April 8, 2001 through March 4, 2012, negotiated cash prices Granger cause forward contract prices and vice versa. However, in regime 2 from March 3, 2012 to May 19, 2013, there is no Granger causal relation between negotiated cash prices and forward contract prices. Since we cannot find any threshold effect on cointegrated variables of negotiated cash prices and negotiated grid prices, the Granger causality test was performed with a traditional vector error correction model. Negotiated cash prices Granger cause negotiated grid prices, but no feedback was found for negotiated grid prices. For the pair of negotiated cash prices and formula prices, negotiated cash prices Granger cause formula prices, but not vice versa in both regime 1 and regime 2.

For hogs, no threshold effects were found for any pair of negotiated cash prices and other AMA prices. Based on original VEC models, negotiated cash prices Granger cause swine market formula prices, but swine market formula prices do not Granger cause negotiated cash prices. Negotiated cash prices Granger cause other market formula prices, but not vice versa. Negotiated cash prices Granger cause other purchase prices, but not vice versa as well. For hogs, negotiated cash prices Granger cause other AMAs prices, but we could not find any feedback for other AMAs prices.

Summary and Discussion

Inconsistent cointegration and causality results in subperiods estimated by Lee, Ward, and Brorsen (2012) imply multiple long-run equilibria between negotiated cash prices and other

AMA prices. In addition, the recent changes in cash prices for fed cattle and hogs raise questions about a stable and linear long-run relationship between cash prices and other AMA prices. This paper applies threshold effects of cointegrated variables for negotiated cash prices and other AMA prices to discover the role of negotiated cash prices on AMA prices for fed cattle and hogs. Threshold effects on cointegrated prices are more likely to occur for fed cattle and less likely to occur for hogs. Cash market prices have different influences over each regime for fed cattle but not for hogs. Such results could be important for the recurring Congressional debate related to a proposed ban on packer ownership of livestock, eliminating forward contracts, both of which are AMAs, and the mandated use of the cash market by packers.

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Table 1. Johansen's Cointegration Tests for Fed Cattle, by Subperiod

AMAs for Fed Cattle		Trace statistic		Max statistic		
		λ_{trace}	Critical value	λ_{max}	Critical value	
<i>Subperiod 1, May 2001- April 2004</i>						
Negotiated cash price	r=0	27.29**	19.99	r=0	23.74**	15.67
Forward contract price	r=1	3.54	9.13	r=1	3.54	9.24
Negotiated cash price	r=0	65.26**	19.99	r=0	62.21**	15.67
Negotiated grid price	r=1	3.00	9.13	r=1	3.00	9.24
<i>Subperiod 2, May 2004- April 2007</i>						
Negotiated cash price	r=0	18.31	19.99	r=0	13.24	15.67
Forward contract price	r=1	5.07	9.13	r=1	5.07	9.24
Negotiated cash price	r=0	68.13**	19.99	r=0	62.75**	15.67
Negotiated grid price	r=1	5.38	9.13	r=1	5.38	9.24
Negotiated cash price	r=0	60.66**	19.99	r=0	57.34**	15.67
Formula price	r=1	3.24	9.13	r=1	3.09	9.24
<i>Subperiod 3, May 2007- April 2010</i>						
Negotiated cash price	r=0	11.61	19.99	r=0	8.66	15.67
Forward contract price	r=1	2.94	9.13	r=1	2.94	9.24
Negotiated cash price	r=0	71.03**	19.99	r=0	67.75**	15.67
Negotiated grid price	r=1	3.28	9.13	r=1	3.28	9.24
Negotiated cash price	r=0	19.39	19.99	r=0	16.02**	15.67
Formula price	r=1	3.37	9.13	r=1	3.37	9.24
<i>Subperiod 4, May 2010- April 2013</i>						
Negotiated cash price	r=0	23.20**	19.99	r=0	17.34**	15.67
Forward contract price	r=1	5.86	9.13	r=1	5.86	9.24
Negotiated cash price	r=0	47.76**	19.99	r=0	45.27**	15.67
Negotiated grid price	r=1	2.49	9.13	r=1	2.49	9.24
Negotiated cash price	r=0	23.89**	19.99	r=0	21.39**	15.67
Formula price	r=1	2.50	9.13	r=1	2.50	9.24

Notes: Two ** indicate the rejection of null hypotheses that there are no cointegrating vectors at the 5% significance level. r is the number of cointegrating rank.

Table 2. Johansen's Cointegration Tests for Hogs, by Subperiod

AMAs for Hogs	Trace statistic		Max statistic			
		λ_{trace}	Critical value	λ_{max}	Critical value	
<i>Subperiod 1, May 2001 - April 2004</i>						
Negotiated cash price	r=0	24.98**	19.99	r=0	23.17**	15.67
Other formula price	r=1	1.80	9.13	r=1	1.80	9.24
Negotiated cash price	r=0	30.11**	19.99	r=0	28.46**	15.67
Swine formula price	r=1	1.65	9.13	r=1	1.65	9.24
Negotiated cash price	r=0	10.81	19.99	r=0	10.19	15.67
Other purchase price	r=1	0.63	9.13	r=1	0.63	9.24
<i>Subperiod 2, May 2004 - April 2007</i>						
Negotiated cash price	r=0	16.07	19.99	r=0	10.47	15.67
Other formula price	r=1	5.59	9.13	r=1	5.59	9.24
Negotiated cash price	r=0	20.85**	19.99	r=0	13.06	15.67
Swine formula price	r=1	9.76**	9.13	r=1	7.79	9.24
Negotiated cash price	r=0	11.51	19.99	r=0	8.34	15.67
Other purchase price	r=1	3.17	9.13	r=1	3.46	9.24
<i>Subperiod 3, May 2007 - April 2010</i>						
Negotiated cash price	r=0	17.01	19.99	r=0	15.68**	15.67
Other formula price	r=1	1.33	9.13	r=1	1.33	9.24
Negotiated cash price	r=0	199.57**	19.99	r=0	195.60**	15.67
Swine formula price	r=1	3.97	9.13	r=1	3.97	9.24
Negotiated cash price	r=0	27.22**	19.99	r=0	25.03**	15.67
Other purchase price	r=1	2.19	9.13	r=1	2.19	9.24
<i>Subperiod 4, May 2010 - April 2013</i>						
Negotiated cash price	r=0	20.32**	19.99	r=0	16.07**	15.67
Other formula price	r=1	4.25	9.13	r=1	4.25	9.24
Negotiated cash price	r=0	46.43**	19.99	r=0	37.08**	15.67
Swine formula price	r=1	9.35**	9.13	r=1	9.35	9.24
Negotiated cash price	r=0	33.09**	19.99	r=0	27.05**	15.67
Other purchase price	r=1	6.04	9.13	r=1	6.04	9.24

Notes: Two ** indicate the rejection of null hypotheses that there are no cointegrating vectors at the 5% significance level. r is the number of cointegrating rank.

Table 3. Weighted Ljung-Box and Monti Tests for Nonlinearity in Fed Cattle and Hogs

AMAs	Weighted Ljung-Box Statistic	P-value	Weighted Monti Statistic	P-value
<i>For Fed Cattle</i>				
Negotiated cash and Forward contract	139.78	<0.001	156.90	<0.001
Negotiated cash and Negotiated grid	51.01	<0.001	48.07	<0.001
Negotiated cash and Formula	150.44	<0.001	171.62	<0.001
<i>For Hogs</i>				
Negotiated cash and Swine market formula	46.62	<0.001	45.54	<0.001
Negotiated cash and Other market formula	62.52	<0.001	62.60	<0.001
Negotiated cash and Other purchase	35.79	<0.001	37.47	<0.001

Table 4. The Number of Thresholds in Cointegrating Residuals

AMAs	Linear AR (p) vs 1 threshold SETAR		Linear AR (p) vs 2 thresholds SETAR		1threshold SETAR vs 2 thresholds SETAR	
	Test statistics	Critical value	Test statistics	Critical value	Test statistics	Critical value
<i>Fed Cattle</i>						
Negotiated cash and Forward contract	34.82	12.20	43.47	21.25	8.19	12.01
Negotiated cash and Negotiated grid	12.35	16.83	NA	NA	NA	NA
Negotiated cash and Formula	38.89	12.88	45.58	20.66	6.30	13.44
<i>Hogs</i>						
Negotiated cash and Swine market formula	3.73	12.91	NA	NA	NA	NA
Negotiated cash and Other market formula	12.47	13.81	NA	NA	NA	NA
Negotiated cash and Other purchase	12.77	18.68	NA	NA	NA	NA

Note: (p) is the number of autoregressive. For fed cattle, $p=4$ for a pair of negotiated cash and forward contract prices, $p=1$ for a pair of negotiated cash and negotiated grid prices, and $p=3$ for a pair of negotiated cash and formula prices. For hogs, $p=2$ for a pair of negotiated cash and swine market formula prices, $p=3$ for a pair of negotiated cash and other market formula prices and $p=7$ for a pair of negotiated cash and other purchase prices.

Table 5. Granger Causality Based on TVEC Models for Fed Cattle and Hogs

Regimes	Independent Variables	Direction	Dependent Variables	Test results	Critical Values
<i>Fed Cattle</i>					
Regime 1 (4/8/2001 ~ 3/4/2012)	D_NegCash(4)	→	D_FwdCon	38.39*	11.14
	D_FwdCon(4)	→	D_NegCash	21.12*	
Regime 2 (3/11/2012 ~ 5/19/2013)	D_NegCash(4)	×	D_FwdCon	1.27	5.02
	D_FwdCon(4)	×	D_NegCash	0.96	
No regimes	D_NegCash(1)	→	D_NegGrid	288.17*	9.35
	D_NegGrid(1)	×	D_NegCash	1.92	
Regime 1 (4/8/2001 ~ 3/4/2012)	D_NegCash(3)	→	D_Formula	275.14*	9.35
	D_Formula(3)	×	D_NegCash	0.92	
Regime 2 (3/11/2012 ~ 5/19/2013)	D_NegCash(3)	→	D_Formula	20.09*	16.01
	D_Formula(3)	×	D_NegCash	4.99	
<i>Hogs</i>					
No regimes	D_NegCash(2)	→	D_SwneForm	37.47*	7.38
	D_SwneForm(2)	×	D_NegCash	3.79	
No regimes	D_NegCash(3)	→	D_OthrForm	51.67*	9.35
	D_OthrForm(3)	×	D_NegCash	7.07	
No regimes	D_NegCash(7)	→	D_OthrPurch	134.45*	16.01
	D_OthrPurch(7)	×	D_NegCash	12.87	

Notes: * denotes the rejection of the null hypothesis of no causality at the 0.05% significant level. The critical $\chi^2_{0.05}$ statistic depends on lags of the first-differenced variables. The number in parenthesis is the chosen lag length.