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LIVESTOCK MARKET INTEGRATION AND PRICE DYNAMICS IN THE UNITED STATES

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ABSTRACT

This study examines livestock market integration and price dynamics in the United States using weekly price series of five major livestock market from October 2005 to March 2015. Engle-Granger and Gregory-Hansen bivariate co-integration tests and Johansen multivariate co-integration test were employed to measure integration among spatially separated markets. Price dynamics among livestock markets were investigated by the Vector Error Correction model. The result indicates that all markets are co-integrated with sharing a common stochastic trend suggesting the 'Law of One Price'. The long-run and short-run dynamics of price suggest that the transmission of price changes from one market to another market during the same week is very fast. Livestock markets in the United States are well integrated reflecting satisfactory level of price discovery and market efficiency.

Keywords: Market Integration, livestock market, price dynamics, United State

I. INTRODUCTION

Market integration and price dynamics in livestock markets are important questions to researchers, market participants and policy makers due to geographical distance between production and consumptions areas, bulkiness and perishable nature of livestock products and huge transportation cost (Pendell and Schroeder, 2006). Market integration indicates co-movements of prices and transmission of price signals and information across spatially separated markets. Two markets can be said to be spatially integrated, if trade takes place between these two market, then price in the importing market equals the price in the exporting markets plus the transportation cost of carrying the product from one market to another market (Ravallion, 1986). Price series are said to be co-integrated when a long run linear relation exists among these series (Engle and Granger, 1987). While the presence of co-integration between two price series implies long-run spatial price equilibrium or market integration, the absence of co-integration refers to market segmentation. If markets are segmented, price signals and information will not be transmitted across markets resulting food deficit in some regions and surplus in other regions

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(Ravallion, 1986). Hence, Market integration ensures a regional balance between food-deficit and food-surplus regions (Delgado, 1986).

The study of price dynamic is also important to understand the extent of market integration and the process of price adjustment from one market to another. Two pairs of markets can exhibit the same price co-movement but might have different processes of price adjustment (Goletti *et al.*, 1995). The process of price adjustments between regions may have important implications regarding the structure and behavior of the markets (Bailey and Brorsen, 1985). The process of price transmission can be evaluated in the long-run and short-run using error correction models, where a contemporaneous price in one market is related to its past values and to contemporaneous and past prices in another market. The analysis of market integration and price dynamics is a matter of concern to policy makers to formulate policies regarding food security by ensuring sufficient food distribution and price stabilization.

The livestock industry is one of the top priority industries in the U.S. because of its importance in terms of food supply, income and employment generation. According to the 2012 Census of Agriculture, the number of livestock farm was 913246, almost one-half of the total 2.1 million farms in the United States. The number of livestock farms has declined steadily during the past 15 years, from 1.2 million in 1995 to 913246 in 2012 due to the decline in number of beef operations (USDA, 2012). The Nation’s 94.4 million livestock are spread widely across the country, with a greater concentration generally in the Central States mainly in Colorado, Iowa, Minnesota, Kansas, Nebraska, Texas and Oklahoma. The number of cattle in the United States has reached the peak of 132.0 million in 1975. The Nation’s inventory of livestock has found a steady decline from 2007 to 2014but an increasing trend from 2015 through 2018, to 94.4 million. According to the 2012 Census of Agriculture, small cattle farms (1–49 head) accounted for 69.8 percent of all cattle operations but only 11.6 percent of the total inventory of cattle and calves whereas large farms (1,000 or more head) accounted for just 1.2 percent of all cattle operations but accounted for 36.9 percent of the total U.S. inventory of cattle and calves. In 2017, the livestock industry had the highest value of production at roughly $50.2 billion (USDA, 2017).

The U.S. livestock industry has experienced a significant change in price reporting system in early 2000s. From 1946 to 2001, Agriculture Marketing Service (AMS) under the United States Department of Agriculture (USDA) used to provide the market prices for livestock and meat in its market news program for the livestock market participants (Perry et al., 2005). These reports were generated based on a voluntary price reporting system by producers, packers, feedlot operators and other participants in the cattle industry. In late 1990s, the voluntary price reporting system was criticized for not being representative mainly for two reasons. First, consolidating and shifting of cattle feeding from smaller feedlots to the larger commercial feedlots over the past two decades and second, the rapid adoption of alternative methods of selling cattle by the market participants such as contracts and formula pricing (Grunewald et al., 2004 and Pendell and Schroeder, 2006). Although by the year 2002, 44% of the fed cattle were sold using these alternative methods (USDA, 2004), information on these alternative sale methods was missing from AMS reports. As a result, daily prices collected from regional fed cattle markets for AMS reporters were insufficient to even report a market price quote (USDA, 2001). To address this issue, in 2001, the U.S. Congress passed Livestock Mandatory Reporting Act (LMRA) which requires plants slaughtering 125,000 head of cattle or more annually to report daily prices, volumes, purchase contracts and price agreements to AMS twice daily to facilitate transparent price discovery and provide timely market information to livestock sellers, meatpackers, policymakers, researchers and consumers (Azzam, 2003 and Perry *et al*. 2005). The LMRA was renewed and amended in 2005, 2010 and 2015 (Mathews et al., 2015 and USDA, 2018) and is now expected to provide complete clarity of price and transaction information to the participants in the livestock industry. Therefore, this study is an attempt to investigate the performance of US livestock markets in terms of market integration and speed of price adjustment in the period of LMRA.

Limited studies have addressed market integration and price dynamics in livestock market in U.S., for example, Bailey and Brorsen (1985), Koontz et al. (1990), Schroder and Goodwin (1990), Goodwin and Schroder (1991), Franken *et al.* (2011), and Mathews *et al.* (2015). Bailey and Brorsen (1985) investigated the dynamics of regional fed cattle prices using multivariate autoregressive analysis and the causality test in four regional markets from 1978 to 1983. The study found that price adjustments to new information were not instantaneous and it took about one week to adjust. Koontz *et al.* (1990) examined dominant- satellite relationships in four direct and four terminal fed cattle markets using Granger causality test and it was shown that direct markets dominated. Schroeder and Goodwin (1990) used a multivariate vector autoregressive (VAR) model to identify regional fed cattle prices dynamics in eleven direct and terminal trade cattle markets. The findings showed that cattle markets with larger volumes took less time than those with smaller volumes to fully react to price changes at the other major cattle markets. Goodwin and Schroeder (1991) investigated co-integration and spatial price linkages for 11 U.S. regional slaughter cattle markets and found that co-integration among weekly price series was increased over time and prices were also influenced by distances between the cattle markets. Franken *et al.* (2011) examined the impact of mandatory price reporting on hog market integration in US. The findings indicated that hog markets were co-integrated before and after LMRA but not fully integrated in either period. Finally, Mathews *et al.* (2015) analyzed livestock market efficiency, price behavior and price discovery before and after implementation of LMRA and found that the increased flow of market information with LMRA better informs the broader market. Market efficiency and price discovery were also found to be better in the LMRA period.

Most of the previous studies on livestock market integration were conducted before the mandatory price reporting act. However, livestock market information system has been changed significantly after 2000 due to LMRA, for which a current assessment of spatial fed cattle market integration is inevitable and this study fills the gap by analyzing the most recent picture in the era of LMRA. Therefore, the objective of this study is to investigate spatial market integration and price dynamics among five major U.S. regional livestock markets namely Colorado Direct, Iowa-Southern Minnesota Direct, Western Kansas Direct, Nebraska Direct and Texas-Oklahoma Direct in mandatory price reporting period using the combined weighted-average weekly prices of livestock at five regional markets from October 2005 to March 2015. This study has an important implication to understand the most recent picture of livestock market integration since this market has experienced significant changes over the past decades due to LMRA. The performance of regional livestock markets in terms of price co-integration should be better understood by this study. Consequently, policy makers and market participant will find important information to formulate policies regarding livestock markets and to take business decisions. Additionally, this study is also important to assess the effectiveness of LMRA through quantifying the degree of market integration that can be a significant evidence to extend LMRA for another 5 years.

II. METHODOLOGY

Data

The secondary data consists of weekly price series for five regional markets namely Colorado Direct, Iowa-Minnesota Direct, Western Kansas Direct, Nebraska Direct and Texas Oklahoma Direct has been collected from AMS reports for the period October 2005 to March 2015. Availability of data and representativeness of the cattle industry are the reasons for selecting these markets. These regional markets represent more than 80% of total U.S. livestock marketed in 2005 (Pendell and Schroeder, 2006). Price information was available for different qualities of both live and dressed steers and heifers. Following Rahman et al., 2016, a composite combined price series (one for each market) was constructed for the simplification of analysis. For this purpose, firstly weighted average price series for all qualities was calculated for steers and heifers separately for each respective market. Next step was to convert the dressed prices into equivalent live prices using following formula:

$$Converted\ Price_{ij} = \frac{National\ Average\ Dressed\ Weight}{National\ Average\ Live\ Weight} \times Average\ Dressed\ Price_{ij} - 0.5$$

$where\ i = 1,2,\ldots,5$ represents the five regional markets being analyzed and $j = 1,2$ represents steers and heifers. -0.5 represents \$0.5/cwt transportation cost. Now for each respective market, combined dressed and live prices for steers and heifers were calculated as follows:

$$Combined\ \ Price_{ij} = \frac{\left(N_{ij}^{Live} \times Average\ live\ Price_{ij}\right) + (N_{ij}^{Dressed} \times Converted\ Price_{ij})}{(N_{ij}^{Live} + N_{ij}^{Dressed})}$$

N_{ij}^{Live} means the number of live animals traded in market i for category j (steers or heifers). Similarly, $N_{ij}^{Dressed}$ means number of dressed animals traded in market i for category j. Finally, a composite combined volume weighted average price series including information on both steers and heifers, one for each market was constructed as follows:

$$Composite\ Combined\ \ Price_{i} = \frac{\left(N_{ij} \times Combined\ \ Price_{ij}\right)|_{j=1} + (N_{ij} \times Combined\ \ Price_{ij})|_{j=2}}{(N_{ij}^{Live} + N_{ij}^{Dressed})}$$

Where N_{ij} represents number of animals traded in market i for category j.

The summary statistics of five regional livestock markets are illustrated in Table 1. Mean, minimum and maximum prices of regional livestock markets were almost same for the time period which might be a primary evidence of market integration.

Table 1: Summary statistics of weekly regional livestock prices, Oct. 2005-Mar. 2015

Regional market	Number of obs.	Mean ($/cwt)	Standard deviation	Minimum ($/cwt)	Maximum ($/cwt)	Coeff. of var. (CV)
Iowa-Minnesota	489	108.21	23.92	79.12	170.3	22.11
Colorado	489	108.34	24.00	78.31	173.13	22.16
Nebraska	489	108.68	24.00	78.70	171.53	22.09
Kansas	489	107.98	23.58	78.23	172.83	21.84
Texas-Oklahoma	489	107.98	23.43	77.93	173.00	21.70

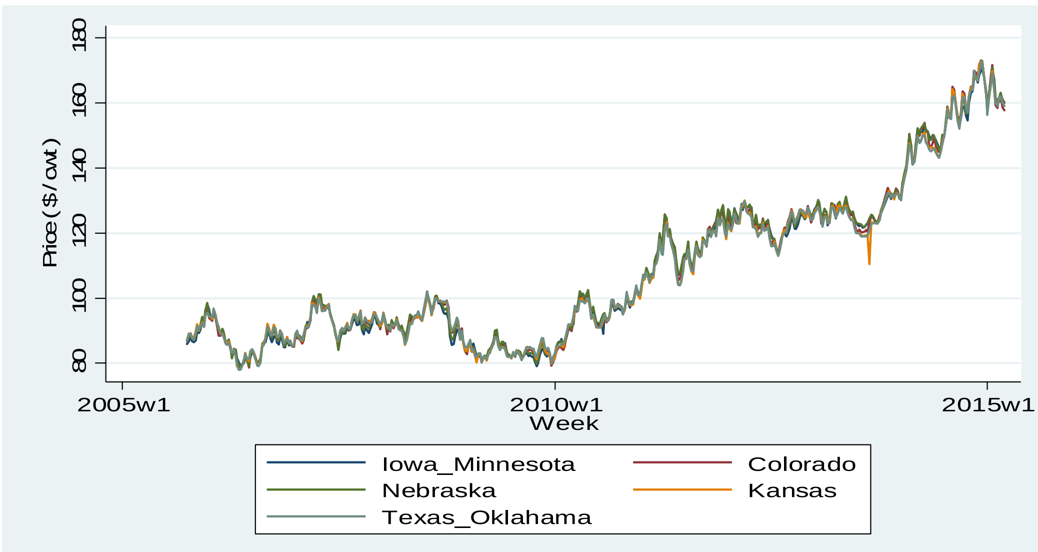

Figure 1. Time series plot of weekly regional livestock prices, Oct. 2005-Mar. 2015

Figure 1 illustrates that weekly livestock prices in five regional markets exhibit fairly similar patterns throughout the study period. Livestock prices were steadily increased after the year 2009.

Preliminary test of time series properties: stationarity test

The first step in testing for co-integration is to test the stationarity of each price series. A time series is (weakly) stationary if its mean and variance are constant over time and the covariance between the two time periods depends only on the distance between the two time periods (Gujarati, 2009). On the other hand, a nonstationary time series has a time-varying mean or a time-varying variance or both. Time series regression based on nonstationary data leads to the phenomenon of spurious regression, in the sense that the regression results look fabulous in terms of high R square and significant coefficient but they look doubtful on further investigation (Granger and Newbold, 1974). Time series literature includes graphical analysis, the co-rrelogram test and unit root test to test the stationarity of a series. Among these tests, unit root tests like Dicky-Fuller (DF) test (Dickey and Fuller, 1979), Augmented Dickey Fuller test (Dickey and Fuller, 1981), Philips-Perron test (Perron, 1989) and few other tests are the formal test of stationarity in a time series. Augmented Dickey Fuller test (Dickey and Fuller, 1981) and Philips-Perron test (Perron, 1989) were used in this study to check the stationarity of price data. The null hypothesis in ADF test is that there is a unit root in the price series. The series is nonstationary if the null hypothesis is not rejected. If the series becomes stationary after first differencing, then the next step is to test co-integration among price series. ADF test tends to have false conclusion under structural break in the time series (Perron, 1989). Hence, Philips-Perron unit root test was also conducted to overcome the limitations of ADF test.

Co-integration tests and price dynamics

Engle-Granger (1987) and Gregory-Hansen's (1996) bivariate co-integration tests and Johansen (1988) multivariate co-integration test were used to investigate how spatially distant livestock markets are linked together via prices. Price dynamics were portrayed by the Vector Error Correction (VEC) model.
The Engle-Granger bivariate methodology was used to test any long run equilibrium relationship between the two price series relationship in the following form:

$$y_t = \beta_1 + \beta_2 x_t + \epsilon_t \quad (1)$$

Where,
y_t and x_t represent the two different price series, $\beta_1, \beta_2 and\ \epsilon_t$ are intercept, slope and error term respectively. In order to test the co-integration between$y_t$andx_t, the stationarity test for the estimated residuals $\widehat{\epsilon_t}$ form equation (1) was done by Augmented Dickey Fuller test. If there is a unit root in the residual series, y_t and x_t are not co-integrated. The Engle-Granger bivariate test is easy to implement but was criticized since the result might depend on price series which is used in the left side. The test was also criticized for testing multiple co-integration relationship and large bias in small sample.

Gregory-Hansen (1996) co-integration test was also used to allow any structural changes in the price series due to major policy change or other kinds of shocks. Co-integrating relationships can be changed by the structural break in the price series. The estimation procedure of Gregory-Hansen is similar to Engle-Granger co-integration test procedure.

Johansen (1988) co-integration test is a multivariate approach for testing co-integration which begins with a Vector Autoregressive (VAR) model:

$$P_t = A_0 + A_1 P_{t-1} + \cdots + A_k P_{t-k} + \varepsilon_t \quad (2)$$

Where, *P*is a (nx1) vector of the price series; *A*'s are matrices of parameters; *k* is lag length; ε is vector of independently and identically distributed residuals. The next step is to reform the VAR model into a Vector Error Correction (VEC) form:

$$\Delta P_t = \tau_0 + \tau_1 \Delta P_{t-1} + \cdots + \tau_{k-1} \Delta P_{t-(k-1)} + \pi P_{t-k} + \varepsilon_t \quad (3)$$

Where, $\Delta P_t$is a (nx1) vector of the price series in first differences; τ_0=A_0; τ's and π are (nxn) matrices of parameters. The number of independent co-integrating vectors is determined by the rank of the matrix $\pi$of the VEC. Co-integration exists if the matrix π has a rank, $r > 0$. If co-integration occurs, there will be *n-r* stochastic trend with prices in *n* markets (Stock and Watson, 1988). All prices are pairwise co-integrated, if there are *n-1*cointegrating vectors. This implies all of the five regional cattle market series have the same stochastic trend when there are four co-integrating vectors. The price series are not fully integrated if there are more than one common stochastic trend.

The Johansen procedure is based on maximum likelihood estimation of the VEC model. To determine the number of co-integrating vectors in the system, the trace and the maximum eigenvalue test statistics are used. The null hypothesis for both tests is that there are at most *r* co-integrating vectors in the system. In the case of trace test, the alternative hypothesis is that there exist more than *r* co-integration vectors. The alternative hypothesis for the maximum eigenvalue test is that the number of co-integration vectors is equal to $r+1$. Price dynamics of livestock markets can be investigated also by using VEC model. The VEC model conveys short-run and long-run information between markets and also determine the relevant direction of the flow of price information.

III. RESULTS AND DISCUSSIONS

Stationarity Test

The results (Table 2) from both ADF and PP tests indicate all livestock market price series were not stationary in levels.

Table 2: Augmented Dickey Fuller and Phillips-Perron unit root test for livestock market price series

Regional market price series	Test statistics in levels		Test statistics in 1st difference	
	ADF (with constant and trend)	PP	ADF (with constant and trend)	PP
Iowa-Minnesota	-2.060	-1.950	-13.473*	-18.912*
Colorado	-2.149	-2.380	-14.342*	-19.909*
Nebraska	-2.043	-2.302	-13.358*	-19.303*
Kansas	-2.174	-2.324	-13.973*	-20.179*
Texas-Oklahoma	-2.145	-2.295	-13.889*	-19.051*

Note: (*) denotes 1% significance level; critical value at the 1% significance level is -3.981 for a model with constant (MacKinnon, 1996)

To check whether the series was integrated of order one I [1], first difference of each price series was taken and data series were tested for non-stationarity again with ADF and PP tests. Now, price series were found to be stationary at 1% significance level in case of both tests. Hence the price series were declared to be integrated of order one I [1].

Co-integration test

Given that price series were all integrated of order one I [1], Engle-Granger and Gregory-Hansen Bivariate test and Johansen's Multivariate Co-integration tests were applied to the price series in levels to examine any long run relationship among price series. Gregory Hansen test was applied allowing change in regime and trend. Lag length was selected according to the minimum Akaike information criterion and lag 2 was found appropriate based on AIC. Table 3 illustrates bivariate co-integration test results for livestock markets. The null hypothesis of no co-integration was rejected for both bivariate tests across all livestock markets. This implies there is an equilibrium relationship between livestock markets. Specifically, all markets were pairwise integrated all over the period.

In order to further investigate, Johansen's test for co-integration was conducted with a linear trend in co-integration equation. If there are *n*-1 co-integrating vectors then all the price series share a common stochastic trend suggesting that the Law of One Price (LOP) holds for the commodity market (Sharma, 2003). The results on both Trace Statistic and Maximum Eigen Value Statistic indicate the presence of four co-integrating vectors in the price series (Table 4). In other words, price series in all five regional livestock markets observed the same stochastic trend. So there was a spatial equilibrium price relationship among all five regional livestock markets which implies that price series did not significantly diverge to one another. These results support the findings of Pendell and Schroeder (2006).

Table 3: Co-integration test results for weekly regional livestock prices

Dependent market/Independent market	Engle-Granger test statistics	Gregory-Hansen test statistics
Iowa-Minnesota/ Colorado	-6.061**	-5.24*
Iowa-Minnesota/ Nebraska	-8.766**	-7.43**
Iowa-Minnesota/ Kansas	-5.843**	-6.27**
Iowa-Minnesota/ Texas-Oklahoma	-5.855**	-6.31**
Colorado/ Nebraska	-5.809**	-5.59**
Colorado/Kansas	-8.657**	-7.79**
Colorado/ Texas-Oklahoma	-7.542**	-9.26**
Nebraska/Kansas	-5.899**	-6.50**
Nebraska/ Texas-Oklahoma	-5.795**	-7.20**
Kansas/ Texas-Oklahoma	-10.002**	-18.71**
1% critical value	-3.90	-5.47
5% critical value	-3.35	-4.95

(**), (*) denotes 1% and 5% significance level respectively

Table 4: Johansen co-integration test results for weekly regional livestock prices

Null hypothesis (Trace)	Alternative hypothesis (Trace)	Trace statistics	5% critical value (Trace)
r = 0	r > 0	225.83	68.52
r ≤ 1	r > 1	139.45	47.21
r ≤ 2	r > 2	72.81	29.68
r ≤ 3	r > 3	27.99	15.41
r ≤ 4	r > 4	0.01	3.76
Null hypothesis(Max)	Alternative hypothesis (Max)	Maximum Eigen value	5% critical value (Max)
r = 0	r = 1	86.38	33.46
r = 1	r = 2	66.64	27.07
r = 2	r = 3	44.82	20.97
r = 3	r = 4	27.98	14.07
r = 4	r = 5	0.01	3.76

Dynamic Analysis of Livestock Market Integration

The dynamics of regional livestock price series can be presented by the VECM. The model was estimated with using lag order 1 based on information criteria. The error correction term measures the speed of adjustment, the length of time needed for prices to be transmitted from one market to another. Table 5 presents the speed of adjustment of prices when any disequilibrium occurs.

Table 5: Long-run and short-run integration results from the Vector Error Correction model estimates

Exogenous variables	Endogenous variables				
	D (Iowa-Minnesota)	D (Colorado)	D (Nebraska)	D (Kansas)	D (Texas-Oklahoma)
Coint. Eq1	-0.03(-0.17)	0.48*(2.31)	0.68**(3.48)	0.51**(2.59)	0.53**(2.77)
Coint. Eq2	-0.21 (-1.16)	-0.46*(-2.33)	-0.03(-0.16)	0.24(1.25)	0.12(0.68)
Coint. Eq3	-0.03(0.10)	-0.39(-1.30)	-0.90**(-3.20)	-0.61*(-3.22)	-0.61*(-2.19)
Coint. Eq4	-0.05(-0.28)	0.16(0.80)	0.03(0.15)	-0.61**(-2.13)	0.07(0.40)
D(Iowa-Minnesota)L1	-0.68**(-4.70)	-0.65**(-3.90)	-0.66**(-4.22)	-0.66**(-4.19)	-0.65**(-4.26)
D(Colorado)L1	0.39*(2.55)	0.18(0.99)	0.32*(1.98)	0.34*(2.00)	0.38*(2.32)
D(Nebraska)L1	0.35(1.62)	0.43(1.76)	0.33(1.44)	0.34(1.45)	0.33(1.43)
D(Kansas)L1	-0.01(-0.05)	-0.17(-1.05)	-0.07(-0.45)	-0.24(-1.58)	-0.13(-0.88)
D(Texas-Oklahoma)L1	0.11(0.70)	0.33(1.80)	0.22(1.29)	0.35*(2.01)	0.18(1.08)

Note: (**), (*) denotes 1% and 5% significance level respectively; t-statistics are in parentheses; D denotes first difference of the price series and L1 denotes lag period 1.

In co-integration equation 1, the adjustment coefficients are significant for all market except Iowa-Minnesota. The coefficient values indicate that there were a quick adjustment of prices ranging between 48 percent to 68 percent within a week during the period. The co-integration equation 3 shows faster price adjustment than equation 1. The adjustment of prices ranges between 61 percent to 90 percent within a week. However, the error correction terms are significant only for Colorado and Kansas market in equation 2 and 4 respectively. The error correction terms confirm that the speed of adjustment among five regional livestock markets towards equilibrium is very fast. The complete price adjustment across markets takes two to three weeks. The short run dynamics of price relationships can be evaluated by the magnitude of estimated lagged coefficients. The coefficients suggest that the transmission of price changes from one market to another market during the same week is faster for most of the cases.

IV. CONCLUSION AND RECOMMENDATIONS

Spatial market integration defines geographic markets, promotes market competitions, ensures price discovery and assesses market performance (Rahman and Palash, 2018). An indirect approach to analyze market efficiency is to measure market integration (Hopcraft, 1987). Moreover, the information on market integration is a vital instrument for policy makers to formulate policies concerning market liberalization and price stabilization. The livestock industry of U.S. has gone through a significant change in price reporting system after the implementation of Livestock Mandatory Reporting Act (LMRA) in 2001, which facilitates complete clarity of price and transaction information to the participants in the livestock industry. This change in price reporting system is expected to increase in spatial market integration and price transmission among different geographical regions. Hence, the objective of this study is to investigate the degree of maker integration and price transmission among five major livestock markets in the United States in the period of LMRA from 2005 to 2015 employing both bivariate and multivariate co-integration tests and Vector Error Correction (VEC) model.

The ADF and PP tests of co-integration suggest that weekly price series of all markets are nonstationary in levels but stationary in first differences. The Engle-Granger and Gregory-Hansen Bivariate test indicate an equilibrium relationship among all five regional livestock market i.e. all market are pairwise integrated. This fact is also supported by Johansen multivariate co-integration test. This implies that all five markets are co-integrated over the period having a common stochastic trend. The results from VEC model indicates transmission of price changes from one market to another market during the same week is very fast both in long-run and short-run. Regional livestock markets in the United States are well integrated reflecting satisfactory level of price discovery and efficient marketing system.

The findings of this study indicates that the availability of complete and timely market information on supply, demand and price, enhance spatial market integration and price transmission. More precise information flows in the integrated markets leaving less room for price difference and arbitrage opportunities. Overall, the findings of this study are useful to policy makers, agribusiness market participants and researchers to understand the degree of market integration and price relationships among livestock markets and to formulate policies to protect the livestock industry. Additionally, the findings of this study have an important policy implication to extend LMRA for another 5 years from 2020 to 2025 since LMRA has a significant contribution to increase market integration and transmission of price signals among regional livestock markets in the United States.

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