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The Impact of Ethanol Production on Spatial Grain Market Relationships

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Abstract

Using cointegration theory, grain markets in Michigan, Kansas, Iowa and Indiana were examined to determine if increased ethanol production affected spatial corn price relationships in these states from 1998 through 2008. It was determined that corn prices operated in a stable, long-run equilibrium from 1998 through 2008 and increased ethanol production did not have an effect on this relationship. These findings suggest policy boosting ethanol production has not altered relationships between spatially dispersed corn markets. In addition to policy makers, this information is also useful to farmers and commodity traders who utilize market information when managing their businesses.

Keywords: cointegration, ethanol, grain markets, spatial relationships

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Introduction

The production of corn-based-ethanol in the United States has steadily increased from 1998 to 2008. The creation of laws at the federal, state and local levels of government is a central reason for the growth of the ethanol industry. From September 1998 to June 2008 ethanol production increased from 1.4 billion gallons per year to 9 billion gallons per year and the number of ethanol plants in the United States increased from 50 to 170 (Renewable Fuels Association 2009). While ethanol production increased by nearly 550% from 1998 to 2008, corn production only increased by approximately 24%, from 9.8 billion bushels to 12.1 billion bushels (United States Department of Agriculture 2009). As illustrated by table 1, from 1998 to 2008 the percentage of corn used in the production of ethanol in the United States increased from 5% to 27%. As the percentage of corn used in the production of ethanol in the United States has increased, the proportion of corn used in the production of other components of corn demand has remained steady or declined (Anderson and Coble 2010). The percentage of corn used in the production of ethanol within the particular states of Michigan, Kansas, Indiana and Iowa also increased from 1998 through 2008 and are also found in Table 1.

Table 1. Percent of Corn Used in the Production of Ethanol

Year	Michigan %	Kansas %	Iowa %	Indiana %	United States %
1998	0.00%	1.51%	14.15%	4.84%	5.18%
1999	0.00%	1.50%	14.24%	4.92%	5.62%
2000	0.00%	1.53%	14.39%	4.51%	5.93%
2001	0.00%	6.29%	16.24%	4.16%	6.72%
2002	7.71%	11.52%	17.15%	5.83%	8.54%
2003	6.95%	11.13%	19.63%	4.68%	10.02%
2004	7.02%	11.49%	22.62%	3.96%	10.40%
2005	6.28%	13.37%	28.24%	4.14%	12.68%
2006	19.42%	22.24%	37.80%	4.36%	16.64%
2007	32.46%	30.75%	35.79%	16.63%	18.00%
2008	32.03%	36.92%	50.20%	36.94%	26.85%

The characteristics of ethanol production in Michigan, Kansas, Iowa and Indiana are reflected in the percentage of corn used in the production of ethanol statistic. For example, from 1998 to 2008 the number of ethanol plants in Michigan Kansas, Iowa, and Indiana increased from zero to five, three to thirteen, four to thirty-nine, and one to twelve, respectively (Ethanol Producer Magazine 2009). Corresponding with these new plants, from 1998 to 2008 annual ethanol production in Michigan, Kansas, Iowa, and Indiana increased from zero to 262 million gallons, 17.5 million gallons to 497.5 million gallons, 693 million gallons to 3.04 billion gallons, and 102 million gallons to 894 million gallons, respectively (Ethanol Producer Magazine 2009).

To determine some of the changes that may have occurred as a result of increased ethanol production, this paper will examine how increased ethanol production in the United States affected spatial corn price relationships at different grain markets in the United States.

Specifically, this paper will determine if increases in ethanol production in Michigan, Kansas, Indiana and Iowa affected spatial corn price relationships between different grain markets throughout their respective states. Before determining how increased ethanol production affected corn price relationships, this analysis will first determine if corn prices at different grain markets in Michigan, Kansas, Indiana and Iowa were cointegrated from 1998 through 2008.

Economically speaking, two variables are cointegrated if they have a long-term, or equilibrium, price relationship between them (Gujarati and Porter 2008). Because corn prices at grain markets throughout a state operate within the same geographical procurement market, it is expected that corn prices at different grain markets throughout a particular state will be cointegrated and thus have a long term, equilibrium price relationship. Once this relationship is determined, this study will examine whether existing spatial corn price relationships at grain markets in Michigan, Kansas, Indiana and Iowa were altered because of rapidly increasing ethanol production. Ethanol plant openings created new demand centers for corn which increased the competition for corn and thus increased the flow of information throughout the state concerning corn prices. Increased competition and increased market information in an industry helps to ensure that prices are cointegrated and operate in a stable long-run equilibrium (Goodwin and Schroeder 1991; Brester and Goodwin 1993; Schroeder 1997; Pendell and Schroeder 2006). Therefore, it is possible that increased ethanol production strengthened the relationship of corn prices at different grain markets. If there are years when corn prices at grain markets in Michigan, Kansas, Indiana and Iowa were not operating in a stable long-term equilibrium (not cointegrated), it is possible that increases in the percentage of corn used in ethanol production helped to bring corn price relationships back to a stable long-run equilibrium (cointegrated). Increased competition for a commodity helps to ensure markets are cointegrated and spatial price discrimination in particular regions does not exist (Brester and Goodwin 1993).

Market price relationships regarding increased corn demand in response to ethanol have recently been studied. Harri, Nalley and Hudson (2009) examined changes in the relationships between crude oil and corn prices in risk management strategies for corn producers because of the growing use of corn for ethanol. Using cointegration theory, they found clear evidence that the relationship between corn and oil has strengthened over time as a result of the growing use of corn for ethanol. Anderson and Coble (2010) determined that the strengthening in the relationship between crude oil and corn prices occurred when the corn ethanol production mandates were raised in the Energy Policy Act of 2005.

This paper will be the first research to investigate whether increased ethanol production has strengthened existing relationships among corn prices at different grain markets throughout the Midwestern United States. Government policy is the central reason for increases in ethanol production. If existing corn price relationships have been altered because of government intervention, it is important for policy makers to have this information. Furthermore, corn market participants, such as farmers and merchandisers, need to understand how markets which they trade in have changed since the rapid expansion of the ethanol industry. When grain merchandisers purchase corn from farmers, knowledge regarding relationships among local grain markets is utilized to make a contract. If increased ethanol production has altered corn price relationships at different grain markets, it is useful for both grain merchandisers and farmers to know how corn price relationships at different grain markets have changed.

It is worth noting that grain market's corn price series cointegration has no direct implication on corn price levels. Instead, if corn prices at different grain markets are cointegrated, it is only concluded that there is a long-term, or equilibrium, price relationship found between the corn price series at the different grain markets. At any time period, the cointegrated corn price series at different grain markets may deviate from their equilibrium price relationship, but this deviation will be temporary: there are economic forces that drive the corn price series at different grain markets back toward their long-term equilibrium price relationship (Wooldridge 2006). This distinction is important as this study purposely makes no attempt to understand the net impact of increased ethanol production on corn price *levels,* an issue inherently separate from multi-market price relationships.

The ensuing discussion is aimed at first discovering if corn prices at different grain markets throughout Michigan, Kansas, Indiana and Iowa were cointegrated from 1998 through 2008. Next, it will be determined whether increased ethanol production has altered spatial corn price relationships at different grain markets throughout these states. In addition to a state by state approach to this analysis, a Midwestern United States model will also be created to determine the effect of increased ethanol production on spatial corn price relationships in the Midwestern United States.

Data

Corn price observations from several different grain markets in the Midwestern United States were purchased from Cash Grain Bids Data Service (2008) to determine how increased ethanol production has affected corn price relationships in the Midwestern United States. The purchased data includes daily corn prices collected from every grain market Cash Grain Bids Data Service had data on within 300 miles of Omaha, Nebraska, and within 300 miles of Indianapolis, Indiana.[1] For this study, weekly corn price averages were used and were created from the daily corn price observations recorded by Cash Grain Bids Data Service. Additionally, only weekly corn price averages at grain markets located in Michigan, Kansas, Iowa and Indiana were compiled. McNew and Griffith (2005) also used local corn price data collected from Cash Grain Bids Data Service in their analysis of measuring the impact of ethanol plants on corn basis levels.

Michigan, Kansas, Iowa and Indiana were the states chosen to represent the Midwestern United States in this study. The purchased data set includes price data for fifty-seven grain markets in Michigan, 245 grain markets in Kansas, 511 grain markets in Iowa and 162 grain markets in Indiana. These four states geographically are representative of both the Eastern and Western Corn Belt Region. Additionally, from 1998 through 2008 Iowa annually produced the most corn in the nation (United States Department of Agriculture 2009). Combined Michigan, Kansas, Iowa and Indiana account for approximately fifty-two percent of the national annual production of ethanol (Ethanol Producer Magazine 2009) and about thirty-two percent of the total corn produced in the United States (United States Department of Agriculture 2009).

[1] Budget constraints prohibited purchasing the entire national set of markets tracked by Cash Grain Bids Data Service. Nonetheless, the data purchased collectively captures the majority of grain markets in both the western and eastern cornbelts.

A state by state approach was utilized to determine how increases in ethanol production affected spatial corn price relationships in the Midwestern United States. In each state, the weekly corn price averages recorded at all of the grain markets from September 1998 through June 2008 were complied. Next, two criterions were used to narrow the grain markets to be examined to four grain markets per state. Only four grain markets were examined in each state because of degrees of freedom constraints presented by annual multivariate cointegration testing. The two criterions were (1) completeness of corn price observations in the weekly average corn price series and (2) geographical dispersion between the locations of the different grain markets chosen. Table 2 illustrates which four grain markets were studied in each state along with the characteristics of each weekly average corn price series recorded at each grain market.

Table 2. Weekly Average Corn Price Statistics (cents/bu)

Grain Market	# of Obs.	Mean	Std. Dev.	Minimum	Maximum
Blissfield, MI	512	238	85	145	588
Lake Odessa, MI	512	226	86	137	576
Marlette, MI	512	229	83	136	571
Middleton, MI	512	226	84	136	571
Chapman, KS	512	233	89	144	627
Hillsboro, KS	512	235	87	143	580
Larned, KS	512	241	85	155	576
Osborne, KS	512	230	85	142	555
Algona, IA	512	218	86	129	567
Audubon, IA	512	218	87	127	603
Cedar Rapids, IA	512	242	81	155	583
Chariton, IA	512	225	80	130	557
Columbus, IN	512	235	86	137	586
Delphi, IN	512	242	86	147	592
Greensburg, IN	512	239	83	143	571
Hamlet, IN	512	237	85	143	589

Criterion one noted completeness of corn price observations in the weekly average corn price series as being one way of selecting the proper grain market to study. However, no grain market contained 100% of their weekly corn price observations[2]. Therefore, missing observations were predicted by regressing the Chicago corn price time series with each individual grain market's corn price time series[3]. Weekly average Chicago corn price time series from September 1998 through June 2008 was recorded by the Livestock Market Information Center (2009). All grain markets used in the study were individually missing less than nine percent of their total weekly corn price observations.

[2] Overall, grain markets in these four states were missing 5% of their observations.
[3] Pendell and Schroeder (2006) followed a similar procedure to create missing observations for their cointegration analysis regarding the fed cattle market.

Methods

To determine if increased ethanol production has affected spatial corn price relationships at different grain markets in the Midwestern United States, the first item this analysis investigates is whether corn prices were cointegrated (operating in a stable, long-run equilibrium) from 1998 through 2008. When conducting multivariate cointegration tests one must first determine if the individual corn price series are nonstationary and integrated to the same order (Pendell and Schroeder 2006). To test if the individual corn price series were nonstationary, the Augmented Dickey-Fuller (ADF) unit root test was used. The ADF test utilizes the following OLS regression:

$$\Delta y_t = \alpha + \rho y_{t-1} + \Sigma_{i=1}^{j} \theta \Delta y_{t-i} + \epsilon_t, \quad (1)$$

where y is the particular corn price series, Δ indicates the first difference operator, and j is the lag length that ensures the residual ϵ_t is white noise. The Akaike Information Criteria (AIC) was used to determined proper lag length. The corresponding ADF test statistic is defined as ρ divided by its standard error. Table 3 reports the ADF test results for the corn price series used in our study. The AIC lag lengths that were used in the tests also appear on Table 3.

Table 3. ADF Test Results

Grain Market	Price Series (Levels) Test Statistic	Lag Length	Price Series (First-Differenced) Test Statistic	Lag Length
Blissfield, MI	1.755	2	-7.948*	4
Lake Odessa, MI	1.674	3	-7.851*	4
Marlette, MI	1.199	4	-8.066*	4
Middleton, MI	1.113	4	-7.771*	4
Chapman, KS	2.756	3	-7.747*	4
Hillsboro, KS	1.187	4	-8.462*	4
Larned, KS	1.776	1	-22.561*	0
Osborne, KS	1.578	3	-8.396*	4
Algona, IA	1.023	4	-7.535*	4
Audubon, IA	1.835	4	-7.371*	4
Cedar Rapids, IA	1.242	4	-9.63*	3
Chariton, IA	1.773	1	-8.243*	4
Columbus, IN	1.694	2	-8.816*	4
Delphi, IN	1.663	2	-8.531*	4
Greensburg, IN	0.752	4	-9.422*	3
Hamlet, IN	1.368	4	-7.648*	4

* Indicates rejection of the null hypothesis at 1% significance

As illustrated by Table 3, the null hypothesis that the corn price series contains a unit root was not rejected, implying that the individual corn price series were all nonstationary. Therefore, the next step in this analysis is to determine whether the first differenced corn price series are stationary. After first differencing the corn price series, all of the test statistics were significant at the 1% level. Thus, the null hypothesis that the series contains a unit root was rejected, implying that the first differencing of the individual price series was stationary. Together these results suggest each corn price series was integrated of order one [I(1)] and a multivariate cointegration analysis could be conducted.

Multivariate cointegration theory following Johansen and Juselius (1990) was used for determining whether the corn prices were cointegrated from 1998-2008. This methodology involves estimating the following vector autoregressive model:

2)
$$\Delta Y_t = \sum_{i=1}^{k-1} \tau_{0i} \Delta Y_{t-i} + v_{0t}$$
$$Y_{t-k} = \sum_{i=1}^{k-1} \tau_{1i} \Delta Y_{t-i} + v_{1t}$$

where Y represents a matrix of each of the corn price series (y) which were studied within Michigan, Kansas, Iowa and Indiana. There are two test statistics used to test the null hypothesis that there are at most r cointegrating vectors in the system Y_t. The following equations represent the maximal eigenvalue test statistic and the trace test statistic:

3)
$$\tau_{MAX} = -T \ln(1 - \lambda_{r+1})$$
$$\tau_{TRACE} = -T \sum_{i=r+1}^{t} \ln(1 - \lambda_i)$$

where T represents the total number of observations in the price series and $\lambda_{r+1}, \ldots, \lambda_p$ represents the p-r smallest possible correlations of residual $v_{0t}$with respect to residual v_{1t}.

Results

Cointegration from 1998-2008

Table 4 displays the results from the multivariate cointegration procedure. Corn price series from grain markets in Michigan, Kansas, Indiana and Iowa were analyzed. Referring to table 2, four grain markets' corn price series were analyzed in each state. In addition to the states that were analyzed, a Midwestern United States model was also subjected to cointegration testing to determine if corn prices throughout the Midwestern United States were cointegrated from 1998 through 2008. The Midwestern United States model investigates the cointegration of corn prices at four grain markets, one grain market from each of the above investigated states. The grain markets in Marlette, MI; Hillsboro, KS; Chariton, IA; and Greensburg, IN were chosen for the Midwestern United States model. To determine if the corn price series at the grain markets in Michigan, Kansas, Indiana, Iowa and the Midwestern United States were cointegrated, both maximum likelihood cointegration statistics and trace cointegration test statistics were obtained. Because four markets were used in the cointegration analysis, up to three independent cointegrating vectors may exist. Table 4 illustrates the results of Michigan, Kansas, Indiana, Iowa and Midwestern United States multivariate cointegration testing. Lag lengths were selected at the amount where Akaike's Final Prediction Error (FPE) was minimized.

Table 4. State/Region Specific Grain Markets Multivariate Cointegration Testing Results

Null Hypothesis	Alternative Hypothesis	Michigan Test Stat	Kansas Test Stat	Iowa Test Stat	Indiana Test Stat	Midwest Test Stat	5% Critical Value
Trace Test							
Ho: r=0	H1: r>0	157.36*	121.75*	142.45*	206.22*	106.43*	47.21
Ho: r=1	H1: r>1	82.55*	58.06*	74.75*	121.48*	55.25*	29.38
Ho: r=2	H1: r>2	27.49*	23.50*	32.67*	42.57*	19.87*	15.34
Ho: r=3	H1: r>3	2.21	3.68	1.36	1.60	1.05	3.84
Max Test							
Ho: r=0	H1: r=1	74.81*	63.69*	67.70*	84.74*	51.17*	27.07
Ho: r=1	H1: r=2	55.06*	34.56*	42.08*	78.90*	35.39*	20.97
Ho: r=2	H1: r=3	25.27*	19.82*	31.32*	40.97*	18.82*	14.07
Ho: r=3	H1: r=4	2.21	3.68	1.36	1.60	1.05	3.76

*Indicates rejection of the null hypothesis at 5% significance

Table 4 displays three cointegrating vectors for the five corn price series using both the maximal eigenvalue test statistic and the trace test statistic for the corn price series at grain markets in Michigan, Kansas, Iowa, Indiana and the Midwestern United States. Thus, there was a long-run, or equilibrium, price relationship found between the corn price series at the different grain markets evaluated in Michigan, Kansas, Iowa, Indiana and the Midwestern United States. Therefore, from 1998 to 2008 in Michigan, the corn prices series from grain markets in Blissfield, Lake Odessa, Marlette and Middleton were cointegrated; in Kansas the corn price series at Chapman, Hillsboro, Larned and Osborne were cointegrated; in Iowa the corn price series at Algona, Audubon, Cedar Rapids and Chariton were cointegrated; in Indiana the corn price series at Columbus, Delphi, Greensburg and Hamlet were cointegrated and in the Midwestern United States grain markets at Marlette, MI; Hillsboro, KS; Chariton, IA; and Greensburg, IN were cointegrated.

The Effect of Increased Ethanol Production on Cointegration

This section of analysis examines if increases in ethanol production affected spatial corn price relationships at grain markets in the Midwestern United States. To accomplish this, methodology will follow Brester and Goodwin (1993). Brester and Goodwin determined if the increased consolidation of the wheat industry into only four major firms impacted the competitiveness of the wheat market. The four-firm concentration ratio in the United States wheat milling industry increased from 37% to 66% from 1980 to 1991. To determine if this impacted wheat price relationships, they first estimated annual cointegration statistics from wheat markets that represented different regions of the United States. The annual cointegration test statistics can be thought of as a measure of the degree of cointegration over time. A larger statistic indicates a strong degree of cointegration (Goodwin and Schroeder 1991; Brester and Goodwin 1993; Schroeder 1997). For years 1980 through 1991, they estimated the annual cointegration statistics of the Kansas City, Houston, Omaha and Portland wheat price series in addition to the Kansas

City wheat middlings and flour price series. Next, Brester and Goodwin regressed their annual cointegration test statistics on the four-firm concentration ratio of the United States wheat milling industry to determine if the increased four-firm concentration ratio in the United States wheat milling industry affected the annual cointegration of wheat prices at different wheat markets. Brester and Goodwin found that the four-firm concentration ratio was negatively correlated and weakly related to the degree of annual cointegration between wheat prices and Kansas City wheat middlings and flour price series. Therefore, Brester and Goodwin concluded that the four-firm concentration ratio negatively (although weakly) did affect the cointegration of wheat, flour and wheat milling prices.

Similarly, this analysis will determine if increased ethanol production affected the cointegration of corn prices a different grain markets in the Midwestern United States. Specifically, this study will determine if increased local demand for corn and increased market information regarding the corn market caused an increase in the degree of cointegration between corn prices at different grain markets in the Midwestern United States. To accomplish this, this study first estimates the annual degree of cointegration statistics between corn prices at the previously studied grain markets within the previously studied states. Table 5 displays the annual cointegration maximal eigenvalue test statistics. The proper lag lengths were determined by the minimum value of the FPE but are excluded to save space. The annual test statistics for the null hypothesis r=3 have also been excluded from Table 5 to save space. The annual cointegration trace statistics for the studied grain markets were recorded but also excluded from table 5 to save space.

Following Brester and Goodwin, the maximal eigenvalue test statistics for the years 1998 through 2008 were then regressed on the percentage of each state's corn production which was used in the production of ethanol. To run this regression, an ordinary least squares approach would not be sufficient because our regression contains a non normal distribution. A non normal distribution results because the dependent variable in this model is the maximal eigenvalue test statistics. Therefore, Efron's bootstrapping technique was used to solve the problem of a nonnormal distribution. Brester and Goodwin also utilized Efron's bootstrapping technique in their analysis. Efron's bootstrapping technique regurgitates a given sample over and over again and then obtains the sampling distributions of the parameters of interest to fix the problem of non normal distribution (Gujarati and Porter 2009).

Using Efron's bootstrapping technique with 1,000 replications, the result of regressing the annual cointegration maximal eigenvalue test statistics (MAXE) obtained in Michigan, Kansas, Iowa, Indiana and the Midwestern United States on percent of corn used in the production of ethanol (PCE) in these states and region is found in table 6. Also found in table 6 is whether the increase in the number of ethanol plants (EP) in Michigan, Kansas, Iowa, Indiana and the Midwestern United States altered the annual degree of cointegration of corn prices in these states and region[4]. This was determined by using Efron's bootstrapping technique with 1,000 replications to regress the annual cointegration maximal eigenvalue test statistics (MAXE) for Michigan, Kansas, Iowa, Indiana and the Midwestern United States on the number of ethanol plants (EP) in these states and region.

[4] For the Midwestern United States model, the percentage of corn used in the production of ethanol is equal to this combined percentage for states Michigan, Kansas, Iowa and Indiana. Similarly, the number of ethanol plants in the Midwestern United States model is equal to the number of ethanol plants in Michigan, Kansas, Iowa and Indiana.

Table 5. State/Region Specific Grain Markets Annual Cointegration Tests

		Maximal Eigenvalue Test Statistic					
Time Period	Null Hyp. Ho:	Michigan	Kansas	Iowa	Indiana	Midwest	5% Critical Value
Sept. 1998-1999	r=0	26.78	19.59	25.68	27.73*	49.11*	27.07
	r=1	17.77	10.84	16.70	11.79	15.51	20.97
	r=2	6.57	8.14	12.66	6.95	9.37	14.07
1999-2000	r=0	34.29*	34.02*	56.25*	35.96*	23.65	27.07
	r=1	19.32	19.96	25.38*	29.14*	12.58	20.97
	r=2	16.22	12.48	9.90	6.23	5.76	14.07
2000-2001	r=0	75.55*	35.85*	41.41*	32.29*	31.72*	27.07
	r=1	13.47	17.13	25.80*	26.22*	14.79	20.97
	r=2	11.28	15.05	16.19	9.74	11.58	14.07
2001-2002	r=0	30.12*	32.49*	91.75*	42.87*	25.25	27.07
	r=1	21.54*	21.93	33.73*	26.63*	18.36	20.97
	r=2	5.28	18.88	20.73*	5.29	10.51	14.07
2002-2003	r=0	51.14*	42.68*	34.41*	52.87*	26.17	27.07
	r=1	37.35*	20.69	21.59*	16.76	19.26	20.97
	r=2	25.42	1.70	15.87*	5.81	3.16	14.07
2003-2004	r=0	22.02	54.49*	24.58	69.66*	30.9*	27.07
	r=1	11.50	25.05*	12.52	15.10	10.7	20.97
	r=2	4.64	12.77	7.43	9.07	8.53	14.07
2004-2005	r=0	25.20	51.31*	22.47	15.97	31.24*	27.07
	r=1	10.69	28.2*	12.15	14.94	8.17	20.97
	r=2	9.36	19.47*	8.42	5.83	4.76	14.07
2005-2006	r=0	64.51*	31.52*	49.46*	22.38	51.75*	27.07
	r=1	30.35*	18.43	26.32*	11.83	29.92*	20.97
	r=2	12.28	7.94	8.73	6.17	17.19*	14.07
2006-2007	r=0	32.49*	34.30*	36.36*	30.48*	21.98	27.07
	r=1	11.08	18.21	15.12	19.77	16.70	20.97
	r=2	8.13	9.91	9.07	8.88	4.59	14.07
2007-2008	r=0	24.63	29.08*	19.94	72.97*	22.01	27.07
	r=1	19.69	25.94*	10.59	25.77*	11.27	20.97
	r=2	7.82	5.69	7.09	10.03	5.74	14.07
2008- June 2008	r=0	22.74	93.42*	45.63*	28.82*	56.40*	27.07
	r=1	14.46	35.24*	14.15	17.31	14.95	20.97
	r=2	9.29	15.06*	6.25	10.79	11.57	14.07

*Indicates rejection of the null hypothesis at 5% significance

Table 6. Efron's Bootstrapping Results

	Michigan	Kansas	Iowa	Indiana	Midwest
CE intercept	43.10*	28.67*	47.29*	38.37	26.54*
PCE coefficient	-57.81	96.74	-28.35	10.51	61.81
R-squared	0.1515	0.3391	0.0273	0.0032	0.1100
EP intercept	42.93*	20.36	46.87*	38.44	25.53*
EP coefficient	-3.69	3.45	-0.43	0.51	0.93
R-squared	0.1499	0.3399	0.0568	0.0113	0.0800

* Indicates significance at the five percent level

As evidenced by Table 6, the Michigan, Kansas, Indiana, Iowa and Midwestern United States percentage of corn used in the production of ethanol is not significantly different from zero and several models had a poor R^2. Therefore, the percentage of corn production used in the production of ethanol in Michigan, Kansas, Iowa, Indiana and the Midwestern United States is not significantly correlated with the annual cointegration maximal eigenvalue test statistic. This process was also performed by using Efron's bootstrapping technique with 1,000 replications to regress the annual trace test statistics on the percent of corn production used in the production of ethanol in the studied states and region. Similar to the previous regression, the percentage of corn used in the production of ethanol in the studied states and region was not significantly different from zero. Therefore, the increase in the percent of corn used in the production of ethanol has not had any effect on corn price relationships at grain markets in Michigan, Kansas, Iowa, Indiana and the Midwestern United States.

Also evidenced by table 6, the coefficient for the number of ethanol plants in Michigan, Kansas, Iowa, Indiana and the Midwestern United States is not significantly different from zero and several models again had weak in-sample fits. Therefore, the number of ethanol plants in the studied states and region is not significantly correlated with the annual cointegration maximal eigenvalue test statistic[5]. Therefore, the increase in the number of ethanol plants in the studied states and region has not had any impact on corn price relationships at the evaluated markets.

Summary

From 1998 through 2008, corn prices at grain markets in Michigan, Kansas, Indiana, Iowa and the Midwestern United States were cointegrated. Therefore, from 1998 through 2008 corn prices in these states and region operated in a stable, long-run equilibrium. As a result of government policy, ethanol production rapidly increased from 1998 through 2008 which could have impacted corn price relationships. The expansion of the ethanol industry over this time period created increased demand for corn and increased the flow of information regarding corn prices. Several studies have examined how increased competition in an industry and increased information about a market can strengthen market price relationships and thus strengthen cointegration between

[5] When the annual trace test statistics were regressed with the number of ethanol plants in the studied states and region using Efron's bootstrapping technique with 1,000 replications the results indicated that the coefficients for the number of ethanol plants in the studied states and region also were not significantly different from zero.

markets (e.g. Goodwin and Schroeder 1991; Brester and Goodwin 1993; Schroeder 1997; Pendell and Schroeder 2006; Harri et al. 2010). However, following Brester and Goodwin (1993) methodology, this analysis was unable to conclude that increased ethanol production from 1998 through 2008 had an effect on corn price relationships at grain markets in the Midwestern United States.

If grain market's corn price series are cointegrated, this has no implication on corn price levels. Instead, if corn prices at different grain markets are cointegrated, it is only concluded that there is a long-term price relationship found between the corn price series at different grain markets. Additionally, if corn price series at the different grain markets are cointegrated, the corn price series relationships may deviate from their equilibrium price relationship, but this deviation is temporary because there are economic forces that drive the relationship between corn price series at different grain markets back toward their long-term equilibrium price relationship.

Despite the fact this analysis only used a subset of grain markets from each state, the grain markets that were analyzed are a good indication of corn price relationships at all the grain markets located throughout Michigan, Kansas, Indiana and Iowa. Therefore, the findings of this study have many implications. Despite increases in ethanol production, spatial price relationships at grain markets in Michigan, Kansas, Indiana, Iowa and the Midwestern United States have not changed. Therefore, from 1998 through 2008, farmers and commodity traders who utilized knowledge regarding the relationships between corn prices at different grain markets in order to make managerial decisions (e.g. initiating hedging positions or timing of sales) were correct if they assumed the relationships between corn prices at different grain markets remained the same. The result of this study is also important for policy makers. This study provides evidence to policy makers that government policy that increased ethanol production did not alter corn price relationships (again, not to be confused with altering corn price levels). Corn price relationships at grain markets in Michigan, Kansas, Iowa and Indiana are the same as they were before the policy driven expansion of the ethanol industry.

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