Spatial Price Discovery, Dynamics, and Leadership in Evolving Distiller's Grain Markets

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Abstract
Recent dramatic growth in corn-based bio-refining has generated considerable growth in the by-product of this process, distiller's grains. Distiller's grains are rapidly becoming important livestock feed ingredient sources. However, little public market information is available on distiller's grain. This study determines spatial and temporal price relationships among distiller's grain markets. Results indicate spatial distiller's grain markets operate somewhat independently suggesting potential arbitrage opportunities and indicating distiller's grain markets are information starved. Furthermore, available futures markets are not viable price risk transfer tools for distiller's grains.

Introduction

Corn-based ethanol production has experienced record production each of the last seven years (Figure 1) resulting in a dramatic increase in distiller's grain production, a by-product of the corn refining process.[1] Strong demand for corn by the ethanol industry contributed to substantial corn and distiller's grain price volatility and encouraged record corn production in 2007. The substantial increase in corn usage by the ethanol refinery industry has resulted in livestock producers, especially diaries and cattle feeders, substituting distiller's grain for corn in feed rations. Distiller's grain markets are in development, no publicly traded cash or futures market exchange exists, and publicly available market information about distiller's grain is sparse. With the growing importance of distiller's grain markets, information is needed regarding spatial and temporal price relationships in the industry to assess market efficiency and to determine whether existing futures markets provide price risk management opportunities for distiller's grain market participants.

The general objective of this study is to determine spatial and temporal price relationships in distiller's grain (DG) markets. Particular objectives include estimating the extent of cointegration in spatial distiller's grain markets, determining whether price leadership is present, and quantifying risk present in hedging DG prices using existing

[1] One 56 pound bushel of corn results in approximately 2.8 gallons of ethanol and 17 pounds of dried distiller's grain.

futures contracts. Assessment of spatial cointegration provides important information regarding the spatial market for DG. If spatial markets are cointegrated, then prices tend to follow each other and arbitrage opportunities across markets are limited. If markets are not cointegrated, then they are operating somewhat independently of each other suggesting opportunities for market arbitrage or selectivity by buyers. If centers of price leadership are present, and markets are cointegrated, this indicates market developments in dominant markets provide considerable information about expected price movements at satellite markets. If centers of price leadership are not present, then the markets discover information simultaneously and do not systematically react to information from dominant market locations. Futures markets are important to consider in this analysis because futures markets are highly visible, well developed, central markets. DG futures markets do not exist, but actively traded corn and soybean meal (SBM) futures are the most probable substitutes for DGs so they are included in the analysis. Finally, the ability to offset distiller's grain price risk using corn and soybean meal futures is incorporated into the analysis to quantify the strength of price relationships for these substitutes and determine whether existing futures markets provide viable cross hedging for DGs.

Distiller's grain prices and spatial markets have not been widely analyzed. Completed studies have assessed cross hedging potential using existing futures contracts for corn and SBM. Early work by Miller (1982) some 25 years ago concluded that cross hedging distiller's grain in corn and SBM futures reduced risk. Coffey, Anderson, and Parcell (2000) concluded that cross hedging corn gluten feed, and DG using corn and SBM futures contracts was unsuccessful in reducing price risk. Brinker, Parcell, and

Dhuyvetter (2007) found that SBM futures are important to include with corn for DG cross hedging, as it holds 20-40% of the hedging weight. Furthermore, results demonstrated that inclusion of SBM futures and corn futures effectively reduces risk when cross hedging DGs.

Price discovery dynamics have been widely evaluated for several commodity markets. Mattos and Garcia (2004) investigated relationships of cash and futures in thinly traded markets. Their analysis of futures markets in Brazil was associated with developing markets and circumstances where liquidity can be problematic. Results of their cointegration analyses illustrated that contracts with greater trade volume were more likely to demonstrate long-run equilibrium relationships, and therefore be cointegrated. However, thinly traded contracts such as corn did not have an evident relationship between cash and futures prices. Nonetheless, they concluded that an unexpectedly low volume of trades were needed to facilitate information flow between cash and futures markets.

Several studies have examined spatial market integration for numerous agriculture commodities (e.g. Djunaidi et al. 2001; Goodwin and Piggott 2001; Goodwin and Schroeder 1991; Hudson et al. 1996; Pendell and Schroeder 2006; and Yang and Leatham 1998). Djunaidi et al. assessed spatial price relationships and efficiency in the rice industry, specifically long grain rice. The analysis evaluated markets in Arkansas, California, Louisiana, Mississippi, and Texas from 1986 to 1998. Through cointegration tests, they concluded that prices of Arkansas and Texas, Louisiana and Mississippi, were cointegrated, and therefore exhibited long run equilibrium relationships. Furthermore, they concluded that markets in the southeast were efficient in terms of price discovery.

They suggested the California market functions in a different manner due to the local demand, and physical characteristics, rather than the geographic location. Yang and Leatham evaluated daily futures price quotes for wheat, corn, oats, and soybeans from 1992 to 1995. They concluded that the four respective markets were not cointegrated when using bivariate models. Hudson et al. used cash prices in Texas and Oklahoma to evaluate the price relationships of cotton cash and futures markets. They employed cointegration and error-correction models to determine the extent and direction of price information flow. Finding cointegration between the two market locations in two of the four years, led them to conclude that the cash and futures market were limitedly related.

The primary contribution of the current research is an evaluation of spatial market relationships and associated price discovery in the emerging DG markets. No published studies have provided this information which is central to assessing market efficiency. Also, we will build upon previous DGs cross hedging studies by increasing the number of market locations included in the analyses to gain a broader geographic assessment and updating the data to include recent price information that incorporates data since the surge in ethanol production. Increasing the number of locations and including data from multiple sources provide a more representative set of price quotes from DG markets.

Methodology

To understand spatial price dynamics in the DG market, we test for the presence of cointegration. Cointegration has been a common practice used to evaluate long-run spatial market equilibrium relationships that may exist between two or more price series. Markets that are cointegrated do not over time diverge from one another, and therefore are considered to have a long-run equilibrium relationship. In contrast, if the price series' are not cointegrated, this suggests that the markets are spatially segmented (Pendell and Schroeder (2006)).

The popular cointegration testing framework as outlined by Engle and Granger (1987) was followed in this analysis. Enders (1995) provides guidelines for the procedures that were applied here. The initial step, determination of stationarity in the individual price series, was conducted by implementing the augmented Dickey-Fuller (ADF) test. The ADF is used to test for the presence of a unit root in a price series, and is exhibited by:

(1) $$\Delta y_t = -\varphi y_{t-1} + \sum_{i=1}^{k} \beta_1 \Delta y_{t-i} + \varepsilon_t \ .$$

where y_t is an individual price series, β_1 is a slope coefficient, and ε_t is a random disturbance term. The appropriate lag length selected was based upon the minimized Akaike information criterion (AIC). The null hypothesis is that φ is equal to zero, where failure to reject the null indicates the series is nonstationary in levels. Furthermore, the individual series become stationary by a differencing process.

To conduct the test for cointegration in a bivariate model, an ordinary least squares regression is carried out on two price series as:

(2) $$y_{1t} = \beta_0 + \beta_1 y_{2t} + e_t \ .$$

The parameter estimates from (2) are then used to find $\hat{e}_t$, and are rearranged as:

(3) $$\hat{e}_t = y_{1t} - \beta_0 + \beta_1 y_{2t} \ .$$

To complete the cointegration evaluation, an ADF is conducted on the saved residuals, $\hat{e}_t$, as follows:

$$(4) \qquad \Delta e_t = -\varphi e_{t-1} + \sum_{i=1}^{k} \beta_1 \Delta e_{t-1} + \varepsilon_t$$

Detection of a unit root upon completion of the ADF on equation (4), suggests that the two price series, Y_{1t} and Y_{2t} are not cointegrated. Another form of this statement could be; if the error term is deemed stationary by completing an ADF and φ is not statistically different from zero, then the two price series, Y_{1t} and Y_{2t} are said to be cointegrated the order (1,1). Therefore, suggesting the prices at the specified market locations are spatially integrated. Multi-variate cointegration, as opposed to univariate cointegration, can also be performed testing for multiple cointegrating vectors. However, because collinearity among prices and interpreting multi-variate cointegration results is difficult, we follow procedures used in many such spatial market integration studies (e.g., Djunaidi et al. (2001); Goodwin and Piggott 2001; Goodwin and Schroeder (1991); Hudson et al. (1996); Pendell and Schroeder, 2006; and Yang and Leatham (1998)) and consider bivariate cointegration tests.

Once the presence of cointegration is evaluated, vector autoregressive models are estimated to determine the speed of price adjustment and price leadership among market locations. Error correction models that included the errors from (3) are used to avoid model misspecification errors as:

$$(5a) \quad \Delta y_{1t} = \alpha_1 + \alpha_{1y} \hat{e}_{1t-1} + \sum_{i=1}^{k} \alpha_{11} \Delta y_{1t-i} + \sum_{i=1}^{k} \alpha_{12} \Delta y_{2t-i} + \varepsilon_{1t}$$

$$(5b) \quad \Delta y_{2t} = \alpha_2 + \alpha_{2y} \hat{e}_{1t-1} + \sum_{i=1}^{k} \alpha_{21} \Delta y_{1t-i} + \sum_{i=1}^{k} \alpha_{22} \Delta y_{2t-i} + \varepsilon_{2t}$$

Where α_{1y} and α_{2y} are the speed-of-adjustment coefficient estimates that allow us to measure the time required to return to equilibrium from a divergence. Here, the absolute value of the speed-of-adjustment estimate is used to determine the rate of adjustment. As the magnitude of the speed-of-adjustment coefficient estimate approaches one, the reaction time is faster relative to when the estimate is near zero. A speed-of-adjustment estimate of zero would imply no response.

Lastly, cross hedging DGs via corn and SBM futures contracts analysis is done using ordinary least squares regression. Through this procedure estimates for the cross hedge ratios are obtained using:

$$(6)\quad y_{it} = \beta_0 + \beta_1 Corn_t + \beta_2 SBM_t + e_t$$

The justification for the format of the cross hedge is explained by Brinker, Parcell, and Dhuyvetter. Because DGs are a corn-derived product, but the protein content is similar to that of SBM, DG may be used as either an energy or protein source in animal diets. Thus a combination of corn and SBM futures was chosen for the cross hedging feasibility analysis.

Data

DG prices from a large number of spatial markets covering numerous years are not publicly available. Therefore, data used in this analysis are a compilation of public sources and private sources that include the USDA Agricultural Marketing Service (AMS) weekly feedstuff's report, *Feedstuff's* magazine, and the University of Missouri's (MU) dairy extension service weekly price quotes. The AMS data include the location of Lawrenceburg, IN. Feedstuff's was used for prices from Atlanta, GA; Buffalo, NY; Chicago, IL; Los Angeles, CA; Okeechobee, FL; Portland, OR; and Minneapolis, MN, and the MU data include Muscatine, IA; Atchison, KS; and Macon, MO. The DG market prices represent spot price quotes, though the characteristics of the quotes vary by source.

Data obtained from AMS and MU are plant-level prices (i.e., the quote comes directly from an ethanol plant producing DGs). The Feedstuff's prices are obtained from grain merchandisers, meaning the prices may include freight to the location, as well as a margin for the trading firm. The DG prices are weekly quotes in dollars per ton, covering the period from the January 2001 through December 2006. Weekly average settlement prices in dollars per bushel for corn and dollars per ton for SBM futures contracts are Chicago Board of Trade quotes obtained from Commodity Research Bureau (CRB).

Results

The first step in analysis of spatial DG price discovery was to determine whether the individual price series were stationary. All of the weekly price series were non-stationary in levels, over the six-year time period. The stationarity tests were estimated using the ADF in Shazam, under the structural format that included a constant, but no trend. All of the price series were stationary in first-differences. Therefore the cointegration technique was appropriate to employ in price levels.

Table 1 reports results of pair-wise cointegration tests for each pairs of DG market locations and the corn and SBM futures markets. There were 27 of 78 (35% of all combinations) market location price pairs cointegrated at the 5% level. Some locations such as Lawrenceburg, Buffalo, and Minneapolis revealed frequent cointegrated pairs. Minneapolis was cointegrated with the majority of the other market locations. Buffalo was the only DG market cointegrated with the corn and SBM futures markets, suggesting that a long run equilibrium relationship between Buffalo and each of the respective futures markets exists. This may be spurious as corn and SBM futures are not cointegrated with each other. Alternatively, some DG pricing involves formula prices based on corn prices and finding cointegration of DG with corn prices is consistent with that practice. However, with all other DG market locations not being cointegrated with corn futures this indicates formula pricing of DG with corn is either not consistent or not a dominant practice.

The presence of cointegrated markets leads to the implementation of an error correction model, structured in the form of vector autoregressive analyses. Even though not all markets were cointegrated with high levels of statistical confidence, we utilized the error correction model for all market comparisons. Granger causality results, as seen in Table 2, show that considerable bi-directional causality is present in the DG markets. The causality results do not reveal a dominant DGs price discovery market location. The Lawrenceburg market, one of the more often cointegrated markets, was generally Granger caused by the other market locations and Granger-caused price changes at all of the other market locations. Understandably, the corn and SBM futures markets lead the DG market locations with little feedback.

Speed-of-adjustment coefficients were estimated to determine how quickly markets respond to deviations from spatial equilibrium (Table 3). The actual estimates of the speed-of-adjustment coefficients are reported in the tables, though the absolute values are used in interpretation. The closer the absolute value of the speed-of-adjustment estimate is to 1.0 signifies that a full price correction occurs within one week. In contrast, an estimate close to 0.0 indicates a very slow market response to a shock in another market. Most of the speed-of-adjustment coefficient estimates are different from zero at the 5% level. However, the estimates range (in absolute value) from 0.028 to 0.216 suggesting that the overall reaction time of disequilibrium across the spatial markets is slow with less than one-quarter of the full adjustment occurring within a week across all market locations.

Cross hedging analyses for DGs using corn and SBM futures contracts for price risk reduction varied noticeably by location. We conducted analysis using just corn or just SBM futures, though the results were inferior to those of using both commodity contracts (lower R-squared and larger RMSE). This is consistent with Coffey, Anderson, and Parcell (2000) who found that individually a corn or a SBM futures contract does not appear to capture the variability in the cash DG market as well as do the two commodity prices together. Therefore, we focus on using both a corn and a SBM futures contract to hedge DGs. The coefficient estimates can be seen in Table 4. Using a combination of the two futures contracts does not provide viable cross hedging. The largest adjusted R-squared is for the Los Angeles market at only 0.09. The low explanatory power indicates poor cross hedging opportunity in corn and SBM futures for DG. Our results indicate less potential than those of Coffey, Anderson, and Parcell who used data from 1991 to through 1998. This indicates the relationship between DG and corn and SBM futures holds less strength in recent years than in the past.

Conclusions

The DG market has expanded rapidly in recent years with the growing bio-fuels industry. Despite its growing importance, the DG market is still developing and publicly available market data are sparse. This study was undertaken to gain insight into DG spatial and temporal price efficiency and opportunity for risk management using existing futures markets. Only one-third of pair- wise DG market comparisons were cointegrated indicating that spatial arbitrage opportunities exist. Furthermore, spatial proximity of the markets was not related to cointegration indicating distance between the markets was not a determinant of strength of price relationship. This means that DG buyers would benefit from shopping around at multiple markets for DG price quotes when buying DG.

Though the DG markets are not generally cointegrated, they are not independent. Granger causality revealed considerable bi-directional information flow with no single or set of markets leading discovery. This suggests that there is not a single dominant market location. Furthermore, the overall slow speed-of-adjustment estimates across markets indicates DG markets do not rapidly adjust to changes in prices at other locations.

Cross hedging DGs via corn and SBM futures contracts does not appear viable using recent data. This suggests some alternative form of price risk management will be necessary in the DG market. Current poor cross hedging opportunity with existing futures contracts might encourage forward pricing or development of a DG futures contract.

Collectively our results suggest a thin and somewhat information-starved DG market. Prices that are not strongly cointegrated across location and slow speed of adjustments indicate distiller's grain markets are not reacting to evolving information at other locations quickly. Though, feedback in Granger causality does suggest some spatial information flow is present.

Opportunities for further research in the DG market are vast. As the market continues to develop and evolve, both the quantity and quality of data will likely improve. The type of information needed to enhance distiller's grain market efficiency is a particularly important concern for future research.

Table 1

Bivariate Cointegration Test Results for Weekly Distiller's Grains Markets, 2001-2006

	Dependent variable											
Independent	Lawrenceburg	Atlanta	Buffalo	Chicago	Los Angeles	Okeechobee	Portland	Minneapolis	Muscatine	Atchison	Macon	Corn
Atlanta	-3.957**											
Buffalo	-3.937**	-1.559										
Chicago	-4.135**	-3.087	-4.300**									
Los Angeles	-4.016**	-3.946**	-3.6254*	-3.334								
Okeechobee	-3.093	-2.063	-2.392	-2.401	-4.188**							
Portland	-2.505	-2.428	-2.717	-3.429*	-2.001	-2.284						
Minneapolis	-3.613*	-3.386*	-3.602*	-3.412*	-3.647*	-3.364*	-1.912					
Muscatine	-3.626*	-2.867	-3.580*	-2.187	-2.996	-3.395*	-2.455	-3.467*				
Atchison	-4.549**	-2.966	-4.239**	-3.405*	-3.303	-3.120	-3.105	-3.929**	-2.893			
Macon	-3.503*	-2.339	-3.310	-3.838*	-2.828	-2.878	-2.124	-3.071	-3.137	-3.097		
Corn	-2.994	-2.665	-3.548*	-2.380	-2.326	-3.044	-2.187	-2.058	-2.940	-1.963	-3.200	
SBM	-3.084	-3.130	-3.509*	-2.301	-3.208	-2.986	-2.264	-2.366	-2.773	-1.995	-2.449	-0.105

*,** denote 5% and 1% significance levels respectively

Table 2

Granger Causality Test P-Values for Weekly Distiller's Grains Markets, 2001-2006

	Lawrenceburg	Atlanta	Buffalo	Chicago	Los Angeles	Okeechobee	Portland	Minneapolis	Muscatine	Atchison	Macon	Corn	SBM
Lawrenceburg		0.162	0.460	0.028*	0.751	0.000*	0.442	0.074	0.143	0.062	0.011*	0.986	0.490
Atlanta	<0.001*		<0.001*	0.001*	0.001*	<0.001*	<0.001*	0.001*	<0.001*	0.000*	<0.001*	0.010*	0.039*
Buffalo	<0.001*	0.182		<0.001*	0.018*	<0.001*	<0.001*	0.030*	<0.001*	<0.001*	<0.001*	0.862	0.043*
Chicago	0.001*	<0.001*	0.013*		0.049*	<0.001*	0.001*	0.736	0.000*	0.001*	0.476	0.147	0.864
Los Angeles	<0.001*	<0.001*	<0.001*	0.001*		<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	0.560	0.929
Okeechobee	0.019*	0.540	0.010*	0.050*	<0.001*		0.016*	<0.001*	0.007*	0.023*	0.008*	0.199	0.010*
Portland	<0.001*	0.000*	0.077	0.001*	0.144	<0.001*		<0.001*	0.001*	<0.001*	<0.001*	0.731	0.156
Minneapolis	<0.001*	0.001*	<0.001*	0.002*	0.001*	<0.001*	<0.001*		<0.001*	<0.001*	<0.001*	0.808	0.005*
Muscatine	0.025*	0.010*	<0.001*	0.001*	0.059	0.161	0.005*	<0.001*		<0.001*	<0.001*	0.180	0.265
Atchison	<0.001*	0.022*	0.001*	0.020*	0.045*	<0.001*	0.000*	0.001*	<0.001*		0.000*	0.076	0.364
Macon	<0.001*	0.000*	<0.001*	0.000*	0.083	<0.001*	0.000*	<0.001*	0.001*	<0.001*		0.543	0.512
Corn	0.057	0.002*	<0.001*	0.008*	0.000*	0.031*	0.001*	<0.001*	0.031*	0.033*	0.005*		0.329
SBM	0.079	0.001*	<0.001*	0.083	<0.001*	0.052	0.000*	<0.001*	0.004*	<0.001*	<0.001*	0.827	

* Represents statistical significant at the 5% level.

Table 3

Speed-of-Adjustment Coefficient Estimates

	Dependent variable											
Independent	Lawrenceburg	Atlanta	Buffalo	Chicago	Los Angeles	Okeechobee	Portland	Minneapolis	Muscatine	Atchison	Macon	Corn
Atlanta	-0.140*											
Buffalo	-0.216*	-0.009										
Chicago	-0.115*	-0.036*	-0.090*									
Los Angeles	-0.149*	-0.065*	-0.085*	-0.060*								
Okeechobee	-0.120*	-0.012	-0.075*	-0.042*	-0.080*							
Portland	-0.094*	-0.024	-0.054*	-0.053*	-0.042	-0.094*						
Minneapolis	-0.139*	-0.050*	-0.085*	-0.039	-0.108*	-0.145*	-0.067*					
Muscatine	-0.111*	-0.041*	-0.004	-0.038*	-0.099*	-0.158*	-0.043*	-0.058*				
Atchison	-0.142*	-0.052*	-0.096*	-0.057*	-0.135*	-0.148*	-0.079*	-0.148*	-0.041*			
Macon	-0.155*	-0.031	-0.079*	-0.037	0.000	-0.142*	-0.071*	-0.053	-0.022	-0.035		
Corn	-0.061*	-0.042*	-0.039*	-0.041*	-0.071*	-0.136*	-0.053*	-0.069*	-0.048*	-0.035*	-0.065*	
SBM	-0.067*	-0.029*	-0.057*	-0.025	-0.028	-0.092*	-0.043*	-0.056*	-0.046*	-0.028*	-0.037*	0.012

* denotes 5% significance level

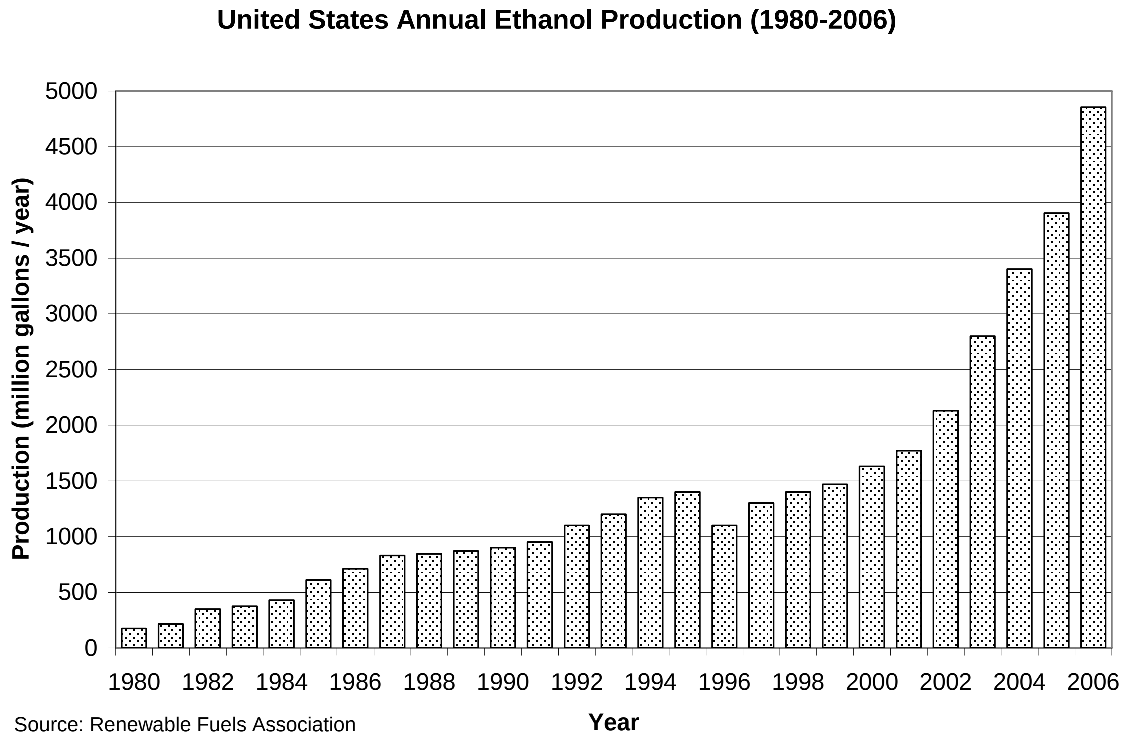
Table 4

Cross Hedging Estimates for DGs using Corn and SBM Futures, Weekly 2001-2006

DG Market	**Intercept**	**Corn**	**Soybean Meal**	**Adj. R^2**
Lawrenceburg	0.128	0.557	0.003	-0.006
	(0.573)	(0.868)	(0.930)	
Atlanta	0.099	1.720	0.055	0.034
	(0.421)	(0.345)	(0.004)	
Buffalo	0.054	1.759	0.059	0.014
	(0.769)	(0.520)	(0.041)	
Chicago	0.110	2.826	0.031	0.004
	(0.565)	(0.319)	(0.302)	
Los Angeles	0.084	9.497	0.077	0.094
	(0.630)	(0.000)	(0.005)	
Okeechobee	0.101	-5.248	0.039	-0.001
	(0.738)	(0.240)	(0.411)	
Portland	0.100	4.175	0.078	0.035
	(0.608)	(0.147)	(0.011)	
Minneapolis	0.111	4.607	0.062	0.025
	(0.582)	(0.121)	(0.049)	
Muscatine	0.081	2.735	0.088	0.061
	(0.590)	(0.218)	(0.000)	
Atchison	0.083	3.189	0.044	0.026
	(0.551)	(0.121)	(0.041)	
Macon	0.077	6.969	0.080	0.057
	(0.691)	(0.015)	(0.008)	

Notes: The numbers in the parentheses are P-values

Figure 1


United States Annual Ethanol Production (1980-2006)
Production (million gallons / year)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
Year
Source: Renewable Fuels Association

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