Regional Dynamic Price Relationships between Distillers Dried Grains and Feed Grains

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Abstract

Distillers dried grains with solubles (DDGS) is emerging as a mainstream substitute in U.S. animal feed rations after biofuel mandates for corn-based ethanol. DDGS is rich in fat and protein content and serves as a competitive feed source in livestock markets. Livestock industries ascertain DDGS feeding value relative to competing grains to find cost-minimizing rations. The price relationships between DDGS and other feedstuffs in feed rations have been typically studied at the national level. However, these price relationships remain ambiguous at a regional level as they likely vary according to livestock sector-specific demand and geographical location. This study identifies dynamic price relationships among DDGS, corn, soybean meal, and livestock outputs in context of specific livestock sectors and their geographic location. Four locations associated with a predominant livestock sector are selected for analysis by measuring density and relative proportion of a livestock sector's grain consumption at the county level. The procedure highlights areas where feed price relationships are likely to be most pronounced and associated with a single sector. A multivariate time-series model is then applied to estimate long and short run DDGS price relationships with other feedstuffs and livestock outputs in these locations. Results from variance decomposition analysis reveal similarities and differences in price relationships across regional markets.

Introduction

U.S. ethanol production surged in the 2000's after the Renewable Fuels Standard (RFS) was introduced in the Energy Act of 2005 and subsequently revised to a higher target level in the Energy Independence and Security Act of 2007 (EPA 2007). The RFS mandates ethanol production from corn increase from 8 billion gallons in 2008 to 15 billion gallons per year from 2015 through 2022. Increased ethanol production resulted in increased production of distillers dried grains with solubles (DDGS), a co-product of the corn-ethanol industry. The U.S. Department of Agriculture (USDA) data shows DDGS production from dry-mill ethanol refineries increased from about 1.8 tons in 2000-2001 to over 36.6 tons in 2010-2011 (Hoffman and Baker 2011).

Following the distillation process, residual corn mash is dried forming a nutrient-rich byproduct with high energy and protein relative to its weight (Fabiosa 2008). DDGS is considered a mid-protein, high-energy feed due and provides a cost-effective substitute for staple feedstuffs such as corn and soybean meal (SBM) (Hoffman and Baker 2011). Stillman, Haley, and Mathews (2009) report U.S. feed expenses approximately doubled from 2006 to 2008 and animal producers rapidly adopted DDGS to offset feed costs in years immediately following ethanol mandates(Anderson, Anderson, and Sawyer 2008). A USDA survey reports a large percentage of dairy, beef and hog producers used or were considering DDGS in feed rations as early as 2006 (USDA 2007). However, optimal use in each sector's feed rationing remains a prevalent research question as the market for DDGS grows (Baker and Babcock 2008; Arora, Wu, and Wang 2010; Beckman, Keeney, and Tyner 2011; Hoffman and Baker 2011).

Studies reports rapid growth in DDGS usage has outpaced research efforts to accurately measure inclusion rates within individual livestock sectors' rationing practices (Dhuyvetter,

1

Kastens, and Boland 2005; Berger and Good 2007; Dooley 2008; Hoffman and Baker 2010). Literature shows these inclusion rates will vary significantly based on DDGS price relative to other feeds, digestive tolerances among species and availability (Van Winkle and Schroeder 2008; O'Brien 2010; Hoffman and Baker 2011). In the absence of precisely-defined demand, understanding how livestock industries use DDGS is a complicated task (Beckman, Keeney, and Tyner 2011). Moreover, determining sector-specific DDGS use is essential to animal operations seeking to minimize feed costs(Moss, Schmitz, and Schmitz 2014), develop effective risk management tools (Bekkerman and Tejeda 2013), and enhance DDGS producer profitability (Stroade et al. 2010).

DDGS use is studied in the literature through identification and analysis of its price interactions with other feedstuffs (Pendall and Schroeder 2006; Anderson, Anderson, and Sawyer 2008). Livestock producers incorporate DDGS into feed rations when its value or utility is high relative to other feed grains (Jones et al. 2007) and dynamic market relationships are formed. These dynamic price relationships concerning DDGS have been studied at the aggregate U.S. level (Van Winkle and Schroeder 2008; Schroeder 2009). However, the research problem includes a spatial dimension as these relationships are likely to vary according to geographically-dependent variations in grain prices and livestock markets (Hoffman and Baker 2010). Furthermore, no studies clearly connect dynamic price relationships between DDGS and other feedstuffs based on the clustered markets of individual livestock sectors.

The objective of the research is to identify dynamic price relationships among DDGS, its competing feed grains, and livestock outputs across specific U.S. regions. The spatial dimension is introduced in the analysis and interpretations are formed within the context of sector-specific livestock markets.

Literature Review

A number of studies in the literature measure analyze price relationships among feed grains in U.S. markets. Specifically, the manner in which DDGS price co-moves with prices of other feed inputs is observed. These co-movements are articulated econometrically through vector autoregressive (VAR) models and cointegration, or the general tendency for market prices to exhibit long-run relationships with each other (Johansen 1988).

Anderson, Anderson, and Sawyer (2008) test for market cointegration between corn prices received in Texas and DDGS wholesale price in Illinois from 1981 through 2007. Results show price relationships, though initially weak, appear to gradually strengthen over time as DDGS markets develop following U.S. Energy Act mandates. Van Winkle and Schroeder (2008) determine weak cointegration between market prices for DDGS, corn and soybean meal (SBM) in select market locations from 2001 to 2006. Schroeder (2009) reexamines DDGS price relationships with a dataset from 2001-2008. The results are comparable to the Van Winkle and Schroeder (2008) and the author concludes DDGS markets are inefficient and information-starved. Murguia and Lawrence (2010) evaluate the performance of several time-series models in estimation of dynamic price relationships. The authors evaluate dynamic feed price relationships and while identifying structural breaks during the analysis period. Strong relationship between SBM, corn, and DDGS are found and suggest potential hedge opportunities. Brinker et al. (2007) also estimate price linkages between DDGS, corn, and SBM. The study reports a DDGS relationship with SBM has strengthen in recent years. A study by Tejeda and Goodwin (2011) test for cointegration among a number of feed grain and cattle markets using price data during pre- and post-ethanol mandate periods and utilize Granger Causality and Impulse Response Functions to estimate price relationships. The authors observe shifts in feed price relationships

following the ethanol mandates between January 1998 to December 2004 and January 2004 to April 2009. They find evidence of livestock producers modifying feed rations in reaction to increased feed prices.

Several studies address spatial characteristics associated with the DDGS research problem. Use of geographic information systems (GIS) is instrumental in analyzing data when spatial context is relevant. Dhuyvetter, Kastens, and Boland (2005) evaluate geographical characteristics of the developing ethanol and coproduct markets. The study uses GIS to map potential DDGS demand and measure potential feed-consumption density. Geographical distributions of grain prices, grain production, livestock populations, and livestock operation size are represented on a county-level basis to provide insight on future ethanol expansion. An analogous study by Dooley and Martens (2008) disaggregate DDGS supply and demand by U.S. Census regions to show spatial characteristics in DDGS markets. Livestock inventories are disaggregated to U.S. Census regions to estimate potential DDGS production and consumption.

Methods and Data

Methods

Time series econometrics offers powerful tools to analyze price relationships. However, interpretation of statistical output is often unclear without a defined economic context. When a spatial dimension exists, developing a spatial context facilitates economic interpretations and provides a framework for comparison. In the case of feed grain markets, this is perhaps based on previous research or common knowledge. For example, individual livestock sectors are synonymous with certain U.S. states or regions, such as dairy in Wisconsin or the West Coast or swine in Iowa and North Carolina. This study argues the use of data-driven, statistical methods

to develop a defensible and intuitive spatial context for interpretations. This approach is motivated both by the geographic diversity of U.S. livestock market as well as availability of spatial data and geoprocessing tools. To address the spatial dimension of the research objective, spatially-referenced data is analyzed within a GIS software interface. The goal is to identify locations where price relationships are relevant, highly pronounced, and representative of one specific livestock sector. The following criteria are developed for the selection procedure:

1. Locations represent a livestock sector common to DDGS literature.

2. Locations represent high-volume markets with clustered feedstuff demand where theory of market efficiency suggests price relationships are developed and pronounced.

3. Locations associate a single livestock sector as the predominant source of feed grain demand where price relationships are indicative of said sector's feed rationing practices.

The spatial analysis begins with exploration of livestock populations reported in the 2012 Census of Agriculture. Livestock inventories for U.S. counties in the lower 48 states are queried and compared with USDA Economic Research Service estimates of DDGS market share as reported by Hoffman and Baker (2011). Four major DDGS-consuming livestock sectors are selected for the analysis; market hogs, fed cattle, dairy cows, and broiler-type chickens.

Each livestock sector was weighted by its UDSA-determined grain consuming animal unit (GCAU) as a proxy measure of potential consumption of DDGS and other feeds. A sector's GCAU is an indexed value of an animal's total annual grain consumption relative to a dairy cow. This non-assumptive measure is used as an effort to avoid specifying a fixed DDGS inclusion rate. The multi-sector GCAU dataset is then joined to an ArcMap shapefile of U.S. counties boundary shapefile.

To accomplish criteria #2, county-level feed demand density is calculated and run through a cluster analysis. County GCAU values for individual sectors are weighted by county area in square miles. This transformation provides a measure of livestock sector density for each county. Livestock sector GCAUs Density is represented by D_{ij} in square miles:

$$D_{ij} = \frac{GCAU_{ij}}{Area_i} \qquad \text{...for sector } j \text{ in county } i$$

Using density values, the Anselin Local Moran's I technique is computed to identify statistically significant clusters of counties with high GCAU density. The Local Moran's I statistic is a measure of spatial association and is defined by Anselin (1995) as:

$$I_i = \frac{x_i - \bar{X}}{S_i^2} \sum_{j=1, j \neq 1}^{n} w_{ij}(x_j - \bar{X})$$

Where x_i is the attribute value for county i, $\bar{X}$ is the mean of that attribute among proximal neighbors, w_{ij} is matrix of weighted spatial relationships between counties i and j, and:

$$S_i^2 = \frac{\sum_{j=1, j \neq 1}^{n}(x_j - \bar{X})^2}{n-1} - \bar{X}^2$$

Where n equals to the total number of contiguous U.S. counties. The Anselin method computes the geographic relationship of counties as the mathematical expression w_{ij}. The spatial weights matrix is created using Inverse Distance Weighted to conceptualize this relationship. In simplified terms, one county's spatial association with a surrounding county is measured by the inverse fraction of the distance between them. Thus, spatial association decreases as a function of distance. The *I* statistic represents a deviational measure of a county's D_{ij} relative to its local mean. This identifies counties where a sector's feed demand density is significantly higher than

that of its neighboring counties. Each county is evaluated according to its own *I* value and that of surrounding counties. Counties are classified into one of the following cluster categories: high values near other high values, high-low, low-low, and low-high. Counties identified as high-high (HH) clusters are extracted from the shapefile and evaluated for the individual sector's contributing GCAU proportion.

To address #3, the procedure must also identify counties where one livestock sector is a predominant source of feed demand. A sector's GCAU density is represented as a proportion, P_{ij}, of county total GCAU density (or the summed D_{ij}) for all sectors (10) reported by the USDA.

$$P_{ij} = \frac{D_{ij}}{\sum_{i=1}^{10} D_{ij}}$$

Using only the extracted county clusters identified by the Moran's I, P_{ij} values are displayed in ArcMap. The procedure is iterated for each of the four sectors and analysis locations are chosen by matching final output locations with available data locations.

The selection procedure is shown in Figures 1-8 for steps 1 and 2. Given the results of the spatial analysis, California, Kansas, Iowa, and Georgia are chosen to represent dairy, cattle, hog, and poultry industries, respectively. These areas are the focus of the cointegration analysis. The procedure forms a context where price relationships are indicative of one specific sector's DDGS usage or feed rationing practices. This may reveal sector- and region-specific trends in DDGS and other feed grain consumption previously unaddressed in the literature.

Cointegration analysis is used to evaluate dynamic price relationships for DDGS, corn, SBM and livestock sector output price at each location. Time-series data require special considerations as they often violate traditional OLS assumptions of consistent error terms. The initial step in a cointegration test procedure is to evaluate whether a data series is stationary, or if the error terms remain consistent over time (Harris 1995). An Augmented Dickey-Fuller (ADF) test is a standard tool to test for unit root presence to ensure proper model specification. The ADF tests the null hypothesis of a unit root which indicates a series is non-stationary. For variables found to be non-stationary, additional unit root test was employed to avoid misdiagnosis in the event of a structural break. Zivot and Andrews (2002) introduce a unit root test where a possible break point is permitted to be endogenously determined by a data series. The null hypothesis of a unit root with a one-time structural break is evaluated versus an alternative of stationary at level with a similar break.

If the series are found to be nonstationary, a vector error correction model (VECM) is necessary to permit contemporaneous variation in the error terms (Johansen 1988). The model, as described by Engel and Granger (1987) and Johansen (1988), is expressed mathematically as:

$$\Delta Y_t = \sum_{i=1}^{K-1} A_i \Delta Y_{t-1} + \prod Y_{t-1} + E_t$$

Where ΔY_t is a n by 1 vector of the first difference of feed price variables, $K-1$ is the lag of the first-differenced price series and A_i (n by n) are the parameters to be estimated. The lagged variable (Y_{t-1}) is the error correction term and its parameter to be estimated is $\prod$, and E_t is the vector of random error terms.

A minimal information criteria (IC) approach is employed to jointly specify appropriate lag lengths and cointegrating ranks of the VECM at each location. The IC is conducted by modeling multiple VECM iterations for each combination of lag length and cointegrating rank, and the final model is selected according to the lowest Akaike Information Criteria (AIC) value. The SIC is preferred as it penalizes additional RHS variables and favors parsimonious models.

Model results are further analyzed through Granger Causality tests and forecast error variance decomposition (FEVD). Granger Causality tests for the presence and direction of short-run price relationships among a model's variables. The FEVD indicates the amount of variance one price contributes to of a price's variance

Data

The data series for California, Kansas, and Iowa are drawn from USDA's Agricultural Marketing Service (AMS) Livestock and Grain Market News Portal and the Georgia series is from *Feedstuffs* magazine. Weekly average price figures from January 6th, 2007 to December 6th, 2014 include: DDGS, corn grain, high-protein SBM, live market hogs, fed cattle, broiler chickens, and nonfat dry milk (NFDM) facilitate the time series analysis.

The spatial analysis portion utilizes county-level animal inventories for ten different livestock and poultry groups reported in the 2012 Census of Agriculture. The ten sectors include beef cows and heifers that calved, fed cattle, dairy cows and heifers that calved, other cattle (including steers, bulls, calves, and heifers not yet calved), market hogs, breeding hogs, broiler chickens, layer chickens, pullet chickens, and turkeys. Dairy cows, fed cattle, market hogs, and broiler chickens are used to represent the GCAU values for location selection.

Results and Discussion

Table 1 in the appendix reports t-statistics and p-values corresponding to each variable for each location. Four unit root tests were computed to evaluate variable price to account for a potential deterministic process. Table 2 reports the Zivot-Andrews t-statistics for all of the variables fall within the critical value range and are not significant. Therefore, we fail to reject the null and may conclude the variables are not stationary with a structural break. The Zivot-Andrews test implies a structural break is present; however, the estimated break points do not suggest a common date and are disregarded. Therefore, ADF test results are considered satisfactory.

Final model specifications are summarized in Table 3. Tables 4-7 report the contribution to each price's forecasted error variance or uncertainty over a twelve-week horizon. In California, variation in corn price is only slightly impacted by the other variables. Corn has a large impact on DDGS at 18.21% at the end of the period. Corn and DDGS contribute 5.67% and 7.28% of variation in SBM price, respectively. SBM is the only substantial contributor to NFDM at 4.6%. For Kansas, DDGS and SBM both account for around 3% of uncertainty in corn price. Corn has a significant impact on both DDGS and SBM at the 12 week mark with 56.08% and 37.47%, respectively. Cattle price variation is only slightly affected by the three feeds. In Iowa, corn's uncertainty is contributed to DDGS, SBM, and Hog at 4.09%, 3.62%, and 3.47% respectively. SBM uncertainty is attributed mostly to corn and DDGS for a combined 19.06%. In Georgia, DDGS and SBM both contribute to roughly 6% of Corn price uncertainty. DDGS forecasted variation is again primarily attributed to corn at 36.70%. SBM uncertainty is affected by corn and DDGS at 6.81% and 8.76% levels, respectively. The three feeds have only marginal contributions to Broiler uncertainty at this location.

Conclusion

This study follows previous research in feed grain price relationships in U.S. livestock markets. The analysis incorporates spatial analysis techniques to identify highly developed markets locations for dairy, fed cattle, swine, and poultry. Results from FEVD analysis at four locations highlight the similarities and differences in price relationships among DDGS, corn, SBM and livestock outputs at each location. Corn price is found to be a large contributor to uncertainty in DDGS price, especially in Kansas. SBM price variation is also largely affected by corn price in Kansas, while the extent of this relationship is lesser in the other areas. Uncertainties in livestock output price are only marginally affected by grain prices with the exception of SBM's relationship with NFDM in California. Analysis of the geographical variation in U.S. livestock markets enhances the interpretive ability of time series methods and addresses research problem found in the literature. Further analysis using Granger Causality and Impulse Response Functions will offer more insight into dynamic feed price relationships in these locations.

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Appendix

Figure 1. Dairy cluster output
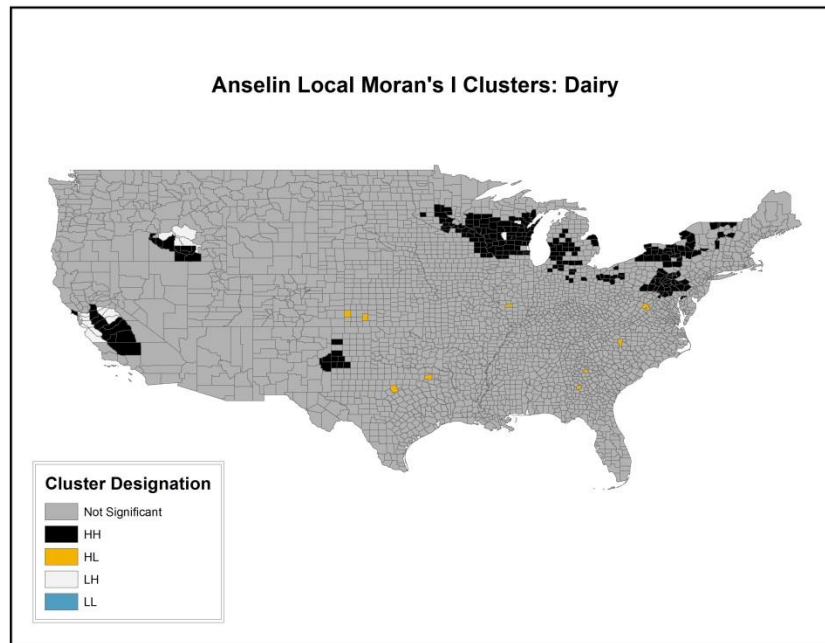
Figure 2. Dairy sector density
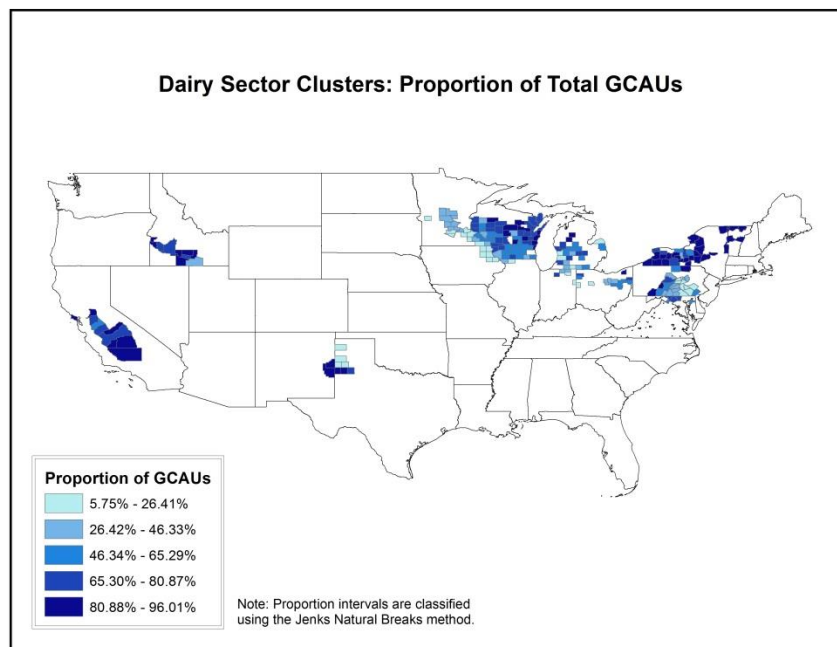
Figure 3. Cattle cluster output
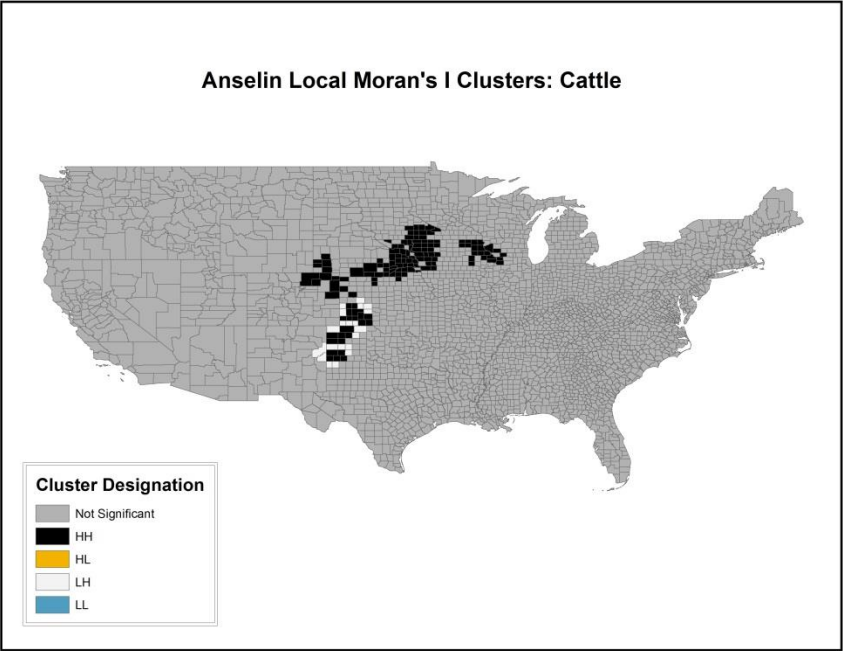
Figure 4. Cattle sector density
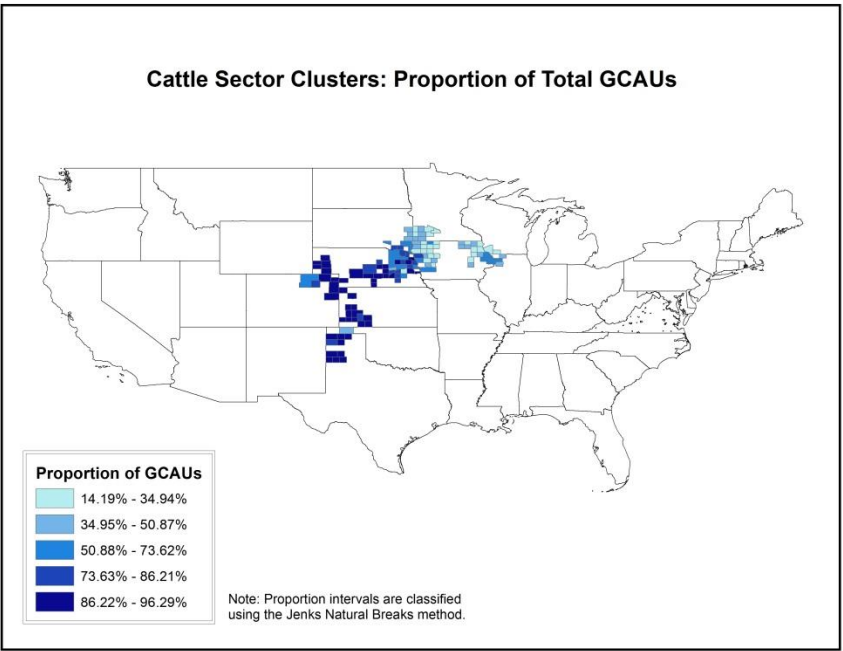
Figure 5. Hog cluster output
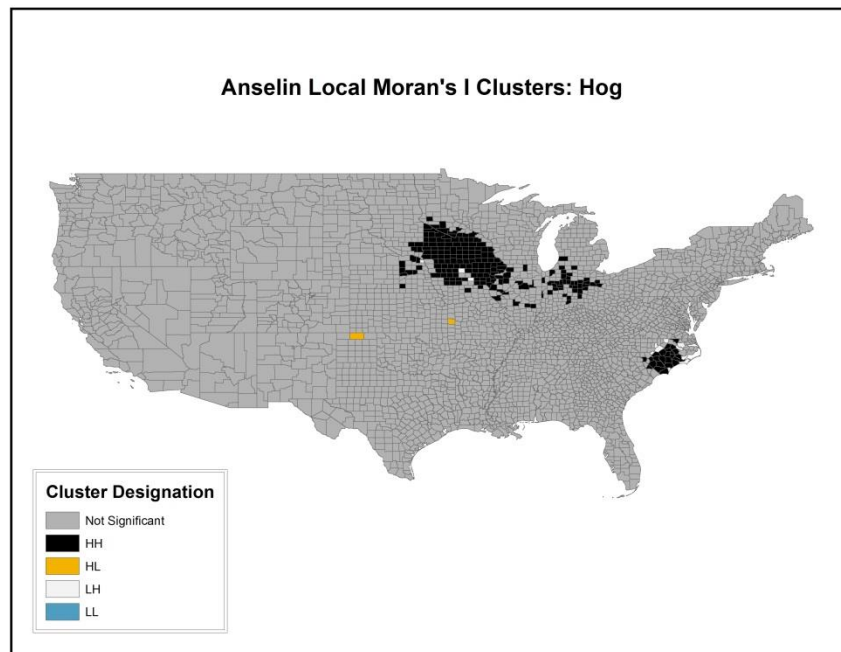
Figure 6. Hog sector density
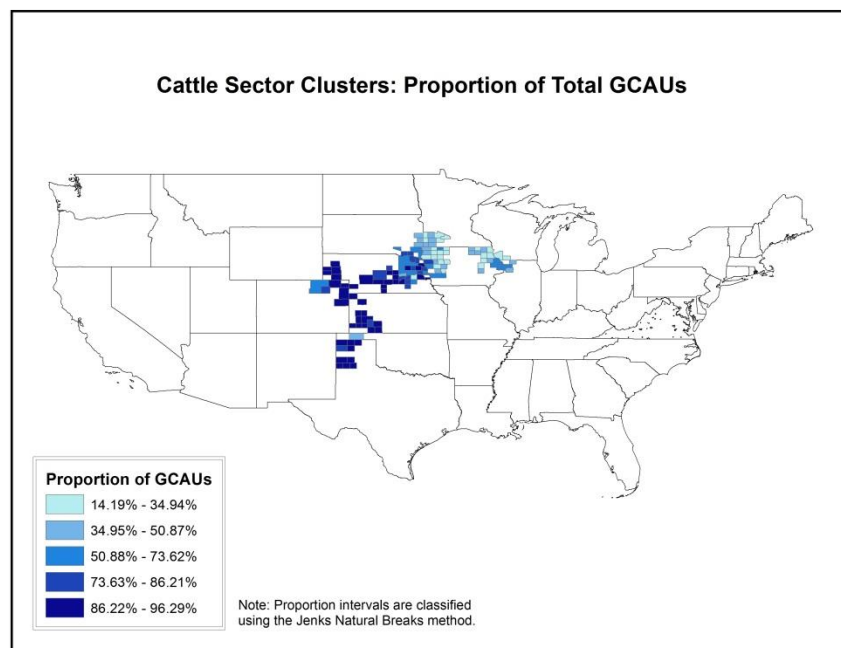
Figure 7. Broiler cluster output

Anselin Local Moran's I Clusters: Broilers

Cluster Designation
- Not Significant
- HH
- HL
- LH
- LL

Figure 6. Hog sector density

Broiler Sector Clusters: Proportion of Total GCAUs

Proportion of GCAUs
- 2.36% - 26.18%
- 26.19% - 47.46%
- 47.47% - 66.13%
- 66.14% - 83.64%
- 83.65% - 100.00%

Note: Proportion intervals are classified
using the Jenks Natural Breaks method.
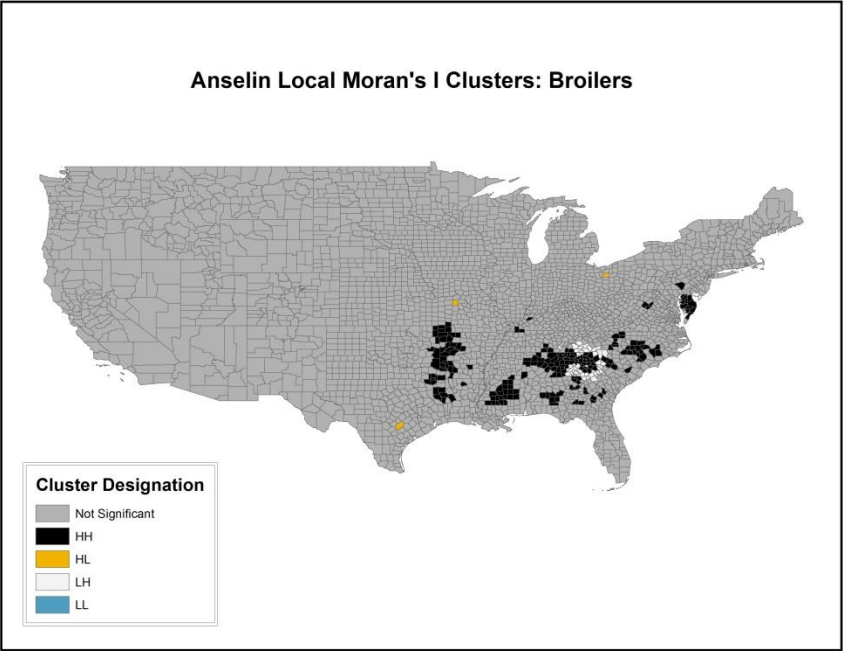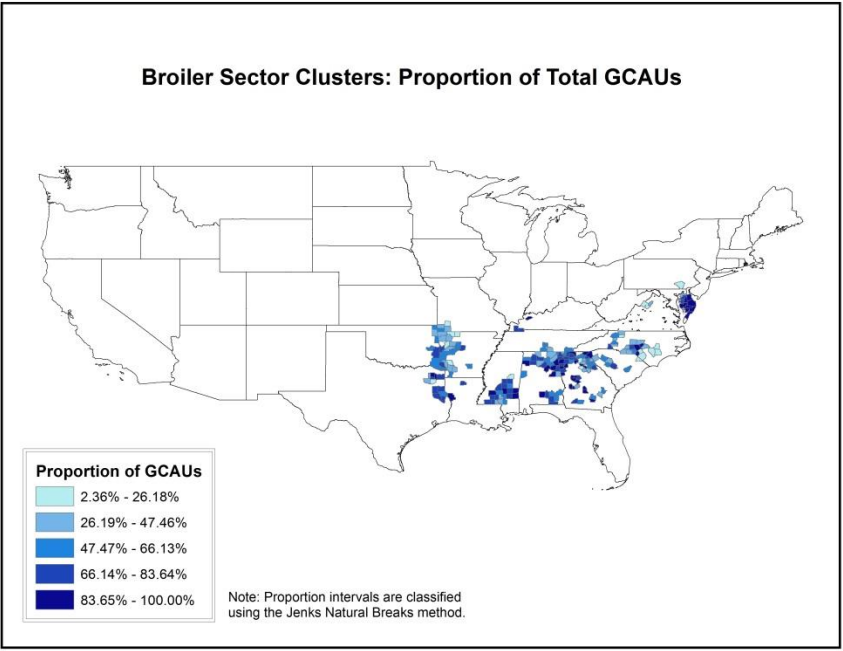
Table 1: ADF Test Results by Location (Null=Unit Root).

| Location	Variable	Type	Lags	ADF	T-Stat.	P-value
California	Output	Level	4	-0.3796	-1.9425	0.5464
		Intercept	4	-2.3447	-2.8768	0.1592
		Trend & Int.	4	-2.4065	-3.4340	0.3750
		D(-1)	2	-5.3240	-1.9424	0.0000
	DDGS	Level	0	-0.2502	-1.9418	0.5955
		Intercept	3	-1.9272	-2.8746	0.3194
		Trend & Int.	3	-1.9935	-3.4306	0.6012
		D(-1)	2	-7.6761	-1.9423	0.0000
	Corn	Level	4	-0.2824	-1.9426	0.5830
		Intercept	4	-1.1372	-2.8774	0.7007
		Trend & Int.	4	-0.8965	-3.4348	0.9532
		D(-1)	4	-8.3203	-1.9428	0.0000
	SBM	Level	4	0.0176	-1.9425	0.6872
		Intercept	4	-1.7946	-2.8762	0.3825
		Trend & Int.	4	-2.9002	-3.4330	0.1648
		D(-1)	4	-8.3411	-1.9427	0.0000
Kansas	Output	Level	2	2.1232	-1.9416	0.9923
		Intercept	2	0.7393	-2.8685	0.9929
		Trend & Int.	2	-1.1107	-3.4211	0.9249
		D(-1)	1	-16.8231	-1.9416	0.0000
	DDGS	Level	4	-0.5019	-1.9417	0.4985
		Intercept	4	-1.9226	-2.8689	0.3218
		Trend & Int.	4	-2.1631	-3.4216	0.5084
		D(-1)	3	-6.9187	-1.9417	0.0000
	Corn	Level	4	-0.4088	-1.9416	0.5359
		Intercept	4	-1.4247	-2.8685	0.5707
		Trend & Int.	4	-1.0964	-3.4210	0.9272
		D(-1)	3	-10.8342	-1.9416	0.0000
	SBM	Level	4	0.0179	-1.9416	0.6879
		Intercept	4	-2.5928	-2.8686	0.0953
		Trend & Int.	4	-3.7165	-3.4212	0.0223
		D(-1)	4	-11.5564	-1.9416	0.0000
Iowa	Output	Level	2	-0.3959	-1.9416	0.5409
		Intercept	1	-3.0224	-2.8687	0.0337
		Trend & Int.	1	-4.3077	-3.4213	0.0034
		D(-1)	1	-11.4797	-1.9416	0.0000
	DDGS	Level	3	-0.7068	-1.9416	0.4102
		Intercept	3	-1.8225	-2.8688	0.3694
		Trend & Int.	3	-2.0813	-3.4214	0.5541
		D(-1)	2	-8.5991	-1.9416	0.0000
	Corn	Level	4	-0.4437	-1.9416	0.5222
		Intercept	4	-1.4872	-2.8684	0.5393
		Trend & Int.	4	-1.1493	-3.4208	0.9181
		D(-1)	3	-10.8953	-1.9416	0.0000
	SBM	Level	4	0.0877	-1.9417	0.7100
		Intercept	4	-2.5300	-2.8693	0.1092
		Trend & Int.	4	-3.4949	-3.4222	0.0414
		D(-1)	4	-11.4884	-1.9417	0.0000
Georgia	Output	Level	2	1.8597	-1.9417	0.9852
		Intercept	2	-0.3037	-2.8690	0.9214
		Trend & Int.	2	-1.9382	-3.4219	0.6323
		D(-1)	1	-4.9577	-1.9417	0.0000
	DDGS	Level	1	-0.5574	-1.9417	0.4753
		Intercept	1	-2.1419	-2.8690	0.2285
		Trend & Int.	1	-2.2666	-3.4217	0.4508
		D(-1)	0	-21.0105	-1.9417	0.0000
	Corn	Level	1	0.4004	-1.9417	0.7986
		Intercept	1	-1.3654	-2.8690	0.5997
		Trend & Int.	1	-1.7258	-3.4217	0.7381
		D(-1)	0	-24.2865	-1.9417	0.0000
	SBM	Level	1	0.1189	-1.9417	0.7196
		Intercept	1	-2.4136	-2.8690	0.1386
		Trend & Int.	1	-4.3700	-3.4217	0.0027
		D(-1)	4	-10.3392	-1.9418	0.0000

Note: Lag length determined by AIC with max length of 4.

Table 2: Zivot-Andrews Test Results by Location (Null=Unit Root with Break).

Location	Variable	Type	Lag length	Z.A. Stat.	Crit. Value	Date
California	Output	Intercept	4	-3.539	-4.930	4/5/2008
		Trend & Int.	4	-3.741	-4.420	11/8/2008
		Both	4	-3.850	-5.080	8/8/2009
	DDGS	Intercept	4	-3.103	-4.930	9/4/2010
		Trend & Int.	4	-2.663	-4.420	5/19/2012
		Both	4	-3.285	-5.080	10/15/2011
	Corn	Intercept	4	-1.427	-2.874	7/3/2010
		Trend & Int.	4	-1.531	-4.420	10/13/2012
		Both	4	-1.949	-5.080	10/6/2012
	SBM	Intercept	4	-3.278	-4.930	3/31/2012
		Trend & Int.	4	-3.020	-4.420	11/24/2012
		Both	4	-3.662	-5.080	7/26/2008
Kansas	Output	Intercept	2	-2.937	-4.930	10/4/2008
		Trend & Int.	2	-2.762	-4.420	5/16/2009
		Both	2	-3.230	-5.080	10/4/2008
	DDGS	Intercept	4	-3.574	-4.930	8/28/2010
		Trend & Int.	4	-3.210	-4.420	12/22/2012
		Both	4	-3.961	-5.080	6/23/2012
	Corn	Intercept	4	-3.002	-4.930	7/27/2013
		Trend & Int.	4	-2.518	-4.420	8/18/2012
		Both	4	-3.257	-5.080	9/4/2010
	SBM	Intercept	-	-	-	-
		Trend & Int.	-	-	-	-
		Both	-	-	-	-
Iowa	Output	Intercept	-	-	-	-
		Trend & Int.	-	-	-	-
		Both	-	-	-	-
	DDGS	Intercept	4	-3.354	-4.930	9/11/2010
		Trend & Int.	4	-3.315	-4.420	7/6/2013
		Both	4	-4.087	-5.080	6/16/2012
	Corn	Intercept	4	-3.066	-4.930	7/27/2013
		Trend & Int.	4	-2.573	-4.420	8/11/2012
		Both	4	-3.265	-5.080	9/4/2010
	SBM	Intercept	-	-	-	-
		Trend & Int.	-	-	-	-
		Both	-	-	-	-
Georgia	Output	Intercept	4	-4.409	-4.930	7/4/2009
		Trend & Int.	4	-4.000	-4.420	9/17/2001
		Both	4	-4.463	-5.080	7/4/2009
	DDGS	Intercept	4	-2.977	-4.930	12/11/2010
		Trend & Int.	4	-2.317	-4.420	7/7/2012
		Both	4	-3.013	-5.080	8/21/2010
	Corn	Intercept	4	-3.215	-4.930	6/29/2013
		Trend & Int.	4	-2.364	-4.420	4/16/2011
		Both	4	-3.235	-5.080	8/21/2010
	SBM	Intercept	-	-	-	-
		Trend & Int.	-	-	-	-
		Both	-	-	-	-

Note: Lag length determined by AIC with max length of 4.

Table 3. Model Selection Summary

	Lag Length	C.E. Rank
California	1	1
Kansas	5	1
Iowa	1	1
Georgia	2	1

Table 4. Variance Decomposition for California

Forecast Variable	Week	Contribution Variable			
		Corn	DDGS	SBM	NFDM
Corn	1	100.00	0.00	0.00	0.00
	12	98.76	0.13	0.78	0.33
DDGS	1	4.14	95.86	0.00	0.00
	12	18.21	81.12	0.56	0.10
SBM	1	1.64	5.71	92.65	0.00
	12	5.67	7.28	86.80	0.25
NFDM	1	0.09	0.57	0.07	99.27
	12	0.23	1.13	4.60	94.04

Note: Cholesky ordering: Corn > DDGS > SBM > NFDM

Table 5. Variance Decomposition for Kansas

Forecast Variable	Week	Contribution Variable			
		Corn	DDGS	SBM	Cattle
Corn	1	100.00	0.00	0.00	0.00
	12	94.04	2.98	2.95	0.03
DDGS	1	6.98	93.02	0.00	0.00
	12	56.08	43.75	0.07	0.09
SBM	1	18.71	0.02	81.27	0.00
	12	37.47	1.34	57.65	3.54
Cattle	1	0.18	0.00	0.03	99.78
	12	0.26	1.02	1.89	96.84

Note: Cholesky ordering: Corn > DDGS > SBM > Cattle

Table 6. Variance Decomposition for Iowa

Forecast Variable	Week	Contribution Variable			
		Corn	DDGS	SBM	Hog
Corn	1	100.00	0.00	0.00	0.00
	12	88.82	4.09	3.62	3.47
DDGS	1	0.33	99.67	0.00	0.00
	12	30.30	66.66	2.47	0.56
SBM	1	11.98	0.06	87.96	0.00
	12	10.46	8.60	78.51	2.42
Hog	1	0.00	0.07	1.10	98.83
	12	1.71	0.59	2.27	95.44

Note: Cholesky ordering: Corn > DDGS > SBM > Hog

Table 7. Variance Decomposition for Georgia

Forecast Variable	Week	Contribution Variable			
		Corn	DDGS	SBM	Broiler
Corn	1	100.00	0.00	0.00	0.00
	12	87.07	6.00	6.25	0.68
DDGS	1	21.67	78.33	0.00	0.00
	12	36.70	62.77	0.39	0.13
SBM	1	13.66	0.15	86.19	0.00
	12	6.81	8.76	83.51	0.91
Broiler	1	0.22	0.62	0.02	99.14
	12	0.16	0.27	2.84	96.73

Note: Cholesky ordering: Corn > DDGS > SBM > Broiler