Time-Varying Price Interactions and Risk Management in Livestock Feed Markets – Determining the Ethanol Surge Effect.

Hernan A. Tejeda

Research/Professional Specialist
North Carolina State University
email: hatejeda@ncsu.edu

Selected Paper prepared for presentation at the Agricultural & Applied Economics Association 2012 AAEA Annual Meeting, Seattle, Washington, August 12-14, 2012

Time-Varying Price Interactions and Risk Management in Livestock Feed Markets – Determining the Ethanol Surge Effect.

Abstract

This paper studies the dynamic effects that the recent growth in supply of Distiller Dried Grains (DDGs), due to the ethanol production surge from corn consumption, has had in relation to other market feeds, specifically corn, grain sorghum and soybean meal. Prior to the U.S. ethanol surge, more than a half of corn's production was consumed as feed for livestock. This amount has dropped to around 40%, as corn is increasingly being used – about 1/3 of U.S. supply - for ethanol production. Ethanol's by-product for feed, DDGs, contains more proteins than corn and serves as substitute in feed rations for livestock, and may likewise affect soybean meal, a protein feed component. In addition, increased corn demand may impact grain sorghum (milo), a similar carbohydrate substitute. A multivariate regime-switching model is applied to two different periods, pre and post- ethanol mandates (Energy Acts of 2005 and 2007), to gauge the dynamic correlations among these markets. Results are consistent with previous literature regarding increasing relationship (correlation) between DDGs and corn, among others. More importantly, an improved characterization of the dynamic inter-relationships between these feed markets not only empirically identifies ethanol surge effects, but serves to assess cross-hedging potential with current corn and soybean meal futures markets. Implications for agricultural price levels, risk management and policy analysis are discussed.

Introduction

This paper studies the dynamic effects that the recent growth in supply of Distiller Dried Grains (DDGs), due to the ethanol production surge from corn consumption, has had in relation to other market feeds, specifically corn, grain sorghum and soybean meal. The substantial increase in the U.S. ethanol production during the past years has been mainly driven by the Energy Acts of 2005 and 2007. The 2005 Act required more than doubling consumption of ethanol from 3.5 billion gals in 2004 to 7.5 billion gals by 2012, a goal that was surpassed during 2008. The 2007 Act requires 36 billion gals of ethanol to be consumed annually by 2022, with recent 2011 production of about 14.3 billion gals. This has led to a significant spike in the amount of corn consumed for ethanol production since more than 95% of ethanol produced in the U.S. comes from corn feedstock. In 2004, about 1.2 billion bushels of corn were used to produce ethanol and by 2011, this number had more than quadrupled to about 5.2 billion bushels (WASDE Report, USDA).

Prior to the ethanol mandates, more than half of corn produced in the U.S. was used as feed for livestock. Yet recent 2011 data has corn for feed dropping to roughly 40%. (WASDE Report, USDA). This decrease in corn use as livestock feed has been accompanied by a significant increase of Distiller's Dried Grains (DDGs) production (10% moisture).[1] This is a by-product from corn produced ethanol, roughly equal in weight to one-third of the corn consumed for ethanol production, and is also used as livestock feed. Specifically, each 56 lb. bushel of corn produces about 2.8 gals of ethanol and 17 lbs. of DDGs (RFA). DDGs contain more protein than corn, and hence may be used not only as carbohydrate feed but also has an impact on soybean meal, which is a main protein feed. In addition, increases in corn demand have likewise affected

[1] This paper does not include Wet Distillers Grains (65 – 70% moisture) or Modified-wet Distillers grain (50 – 55% moisture) prices, leaving these for future study.

some livestock feeders by switching from corn to grain sorghum[2], a main carbohydrate substitute.[3]

These significant changes in grain and feed markets – driven by the substantial increase of corn demand for ethanol production – have affected grain, oilseed and livestock producers, as they have experienced increasing prices and volatility. The rise and volatility of these agricultural commodity prices merit improved methods of assessing the effect they generate, including the further study of potential means to address and/or mitigate the risk they produce by use of improved risk management tools.

This paper begins by investigating the dynamic effects that this recent surge in DDGs production – due to the Ethanol mandates – have had on related feed markets, specifically corn, grain sorghum and soybean meal. Early dynamic studies of agricultural commodity markets by Featherstone and Baker (1987), Goodwin and Schroeder (1991), and Schroeder and Goodwin (1992), applied a Vector Auto-Regressive (VAR) model to the time series data. More recent studies that incorporated the non-stationary properties of time series through a Vector Error Correction (VEC) model include Goodwin and Piggott (2001) and Haigh and Bessler (2004). In this study, a multivariate time-varying model is applied to two different time periods; i.e., pre and post ethanol mandated periods, similar to Tejeda and Goodwin (2011). This is to empirically gauge the dynamic interactions (correlations) among these market prices, and identify the differences that have resulted between these distinct periods. The paper then makes use of the

[2] "During 2008/09, sorghum has been used as a lower priced substitute to corn." pg. 3. *Feed Outlook,FDS-09d* ERS – USDA, March 13, 2009.
[3] Wheat is a close carbohydrate substitute not considered in this paper, but left for future study.

improved characterization of these dynamic market correlations to assess the potential benefit of cross hedging DDGs with current corn and soybean meal futures markets.[4]

A study by Anderson, Anderson and Sawyer (2008) investigated the mitigation of increased ethanol-driven corn prices by using alternative feeds, including DDGs, and Lawrence et al. (2008) addressed the effect of ethanol-induced increasing feed costs on livestock, poultry and dairy markets. Schroeder (2009) addressed price discovery and spatial relationships among DGs (Distiller's Grains – including dried, modified dry, and wet) markets, as well as risk management alternatives for DDGs. Hoffman and Baker (2010) study a methodology for estimating U.S. supply and demand of DDGs, as well as its relationship with corn and soybean meal markets. A different paper by Perrin and Klopefstein (2000), investigated the economic impact of directly feeding Wet Distillers Grains to cattle over Dried Distillers grains, finding advantage of leaving Distillers grains wet for feed over the cost of drying the grains for subsequent feeding.

As for hedging in different markets, a paper by Brorsen, Buck and Koontz (1998) investigated hedging hard red winter wheat in two different trading markets, Chicago and Saint Louis, under utility maximization and risk aversion of the hedger. The study applies price changes to estimate the hedge ratios, which is the best approximation to conditional hedge ratios or time-varying hedge ratios – accounting for up-to-date information – according to Myers and Thompson (1989). A paper by Vukina and Anderson (1993) addressed inter-temporal cross-hedging of fish meal and soybean meal markets by incorporating state space forecasting. On a similar strand, Sanders and Manfredo (2004) incorporate forecast evaluation to determine the statistically significant advantage of one market hedging strategy over that of another market, or over a combination of two markets. Their study likewise estimates unconditional hedge ratios based on

[4] There is a new DDGs futures market operating at CBOT, since April 26, 2010. The dynamic hedging effect of this market is left for future study.

price changes. A recent paper by Brinker et al. (2009) directly applies this procedure, though with price levels instead of price changes, to cross-hedge DDGs with corn and soybean meal futures markets. They find advantages to cross-hedging by using a combination of both markets.

The framework applied to estimate the time-varying hedge ratios for cross-hedging is the mean-varying hedge ratio derived from Myers and Thompson (1989) and is similar to that derived by Brorsen, Buck and Koontz (1998) and Leuthold, Junkus and Cordier (1989). The latter frameworks stem from the five assumptions considered by Benninga, Eldor and Zilcha (1984) to show that the mean-variance hedge ratios developed by Johnson (1960) are likewise consistent with utility maximizing hedge ratios. Let an agent take a spot and futures position at period $t-1$, then the agent's profit at liquidation t is

$$\pi = P_t q_{t-1} - c(q_{t-1}) - (f_t - f_{t-1}) b_{t-1} \tag{1}$$

where π is profit, P_t is the spot price in period t, q_{t-1}, is the spot position chosen at $t - 1$, c is an increasing and convex cost function, f_t is the futures price quoted at period t for delivery at some future date, and b_{t-1}, is sales of futures contracts in $t - 1$ (purchases if negative). Allowing for stochastic production yields an agent that chooses q_{t-1} and b_{t-1} to maximize a linear function of the mean and variance of profit, conditional on available information:

$$\text{Max } E(\pi_t | X_{t-1}) - \frac{\lambda}{2} Var(\pi_t | X_{t-1}) \tag{2}$$

where X_{t-1} is a set of information available at $t - 1$ and λ is a measure of the agent's risk aversion.

Applying optimization first order conditions by differentiating with respect to the futures position and equaling to zero, and simplifying the resulting equation by applying assumptions made by Myers and Thompson (1989) and Brorsen, Buck and Koontz (1998), such as considering non-existing transactions costs, a specific risk aversion level from the agent, and unbiased futures market, the optimal hedge ratio (r^*) becomes:

$$r^* = \frac{b_{t-1}}{q_{t-1}{}^{5}} = \frac{\sigma_{sf}}{\sigma_f^2} \tag{3}$$

with σ_{sf} being the conditional covariance of the spot and futures price on information available at prior period *t-1;* i.e., σ_{sf} = Cov(S_t, $F_t|I_{t-1}$). Likewise, σ_f^2 is the conditional variance of the futures price at *t* on information available at prior period *t-1*; i.e., σ_f^2 = Var($F_t|I_{t-1}$). Here b_{t-1} represents a futures short (sell) position and q_{t-1} cash positions at period *t-1*, prior to period *t* where utility maximization occurs.

This paper proceeds by briefly discussing the econometric methods applied for estimating the time-varying correlations, and hedge ratios for cross-hedging DDGs with corn and soybean meal futures, including the data for two different time periods applied. Results and discussion are subsequently presented.

Methods

Time-varying hedge ratios were estimated considering different time-periods by implementing a framework similar to Garcia, Roh and Leuthold (1995), Manfredo, Garcia and Leuthold (2000) and Tejeda and Goodwin (2011b), and taking into consideration Myers and Thompson (1989). That is, there are two stages for the (ethanol) DDG's producer; the first stage is establishing a DDGs cash position at time *t-1* and a futures position at the same period by using contracts of corn, soybean meal or a mixture of both corn and soybean meal futures contracts. This initial cash price may be equal to the accounting production costs (Vukina and

---

[5] Brorsen, Buck and Koontz (1998) arrive similarly at the optimal futures and spot ratio being: $\frac{x_f}{-x_s}$, estimated as the slope coefficient between futures and spot price changes, and a long (buy) futures position as positive.

Anderson, 1993). Subsequently, at period *t*, the producer sells the DDGs in the market and closes the futures position. Estimations were made considering four weeks (approximately one month) between each period, leaving for future work a period of one week, two weeks, or more than four weeks. Thus the producer's margin is given by:

$$M_{i,t} = S_t - S_{t-4} - r_{i,t-4}\,(F_{i,t} - F_{i,t-4}) \qquad (4)$$

with *i* being either corn or soybean meal. Thus $r_{i,t-4}$ is either one ton of a corn or soybean futures contract on a per ton of DDG basis. For the case of the producer cross-hedging concurrently with a mixture of corn and soybean meal contracts, the margin would be given by:

$$M_{b,t} = S_t - S_{t-4} - r_{c,t-4}\,(F_{c,t} - F_{c,t-4}) - r_{sm,t-4}\,(F_{sm,t} - F_{sm,t-4}) \qquad (5)$$

with *b* being both corn and soybean meal. Here $r_{c,t-4,}$ and $r_{sm,t-4}$ are corn and soybean futures contracts, respectively, on a per ton of DDG basis.

Applying the mean variance framework under the assumptions described previously, the respective minimum hedge ratios are determined from the variance of the margins[6] presented below:

$$Var\,(M_i) = Var(S) + r_i^2 Var(F_i) + 2r_i Cov(S,F_i) \qquad (6)$$

$$Var\,(M_b) = Var(S) + r_c^2 Var(F_c) + r_{sm}^2 Var(F_{sm}) - 2r_c Cov(S,F_c) - 2r_{sm} Cov(S,F_{sm}) + 2r_c r_{sm} Cov(F_c,F_{sm}) \qquad (7)$$

The minimum variance hedge ratios are obtained by partially differentiating the previous variances with respect to r_i in (4) and r_c and r_{sm} in (5) and equating each to zero. Subsequently ratios (*r*) are computed, using Cramer's rule for simplicity in solving derived equations from (7). The optimal hedge ratio for (6) is:

[6] The time scripts are omitted for simplicity.

$$r_i = -\frac{Cov(S,Fi)}{Var(Fi)} \quad (8)$$

being *i* either corn or soybean meal. And the optimal hedge ratios for (7) are:

$$r_c = \frac{Var(Fsm)*Cov(S,Fc) - Cov(S,Fsm)*Cov(Fc,Fsm)}{Var(Fc)*Var(Fsm) - Cov^2(F_c,F_{sm})} \quad (9)$$

$$r_{sm} = \frac{Var(Fc)*Cov(S,Fsm) - Cov(S,Fc)*Cov(Fc,Fsm)}{Var(Fc)*Var(Fsm) - Cov^2(F_c,F_{sm})} \quad (10)$$

for corn and soybean meal, respectively. These latter two time-varying hedge ratios are computed by estimating the time-varying variances and covariance terms from (5).

In order to estimate the conditional time-varying covariance matrix, the conditional changes in price of the respective spot and futures prices are computed. As mentioned previously, a period of four weeks is considered between the two stages (*t-4* and *t*). Thus the price changes for cross-hedging with either corn or soybean meal contracts, or by using a mixture of the two contracts, is given by:

$$R_{,i,t} \mid I_{t-4} = P_{i,t} - P_{i,\, t-4}$$

or $$R_{,i,t} = \Delta P_{i,t} + u_{i,t} \quad (11)$$

with information available at the initial stage, (*t-4*), and *P* being spot prices of DDGs or futures prices of corn and/or soybean meal.

The prediction errors are specified as the time-varying covariance matrix, similar to Garcia, Roh and Leuthold (1995):

$$H_t = E(\varepsilon_t \varepsilon_t' \mid I_{t-4}) \quad (12)$$

The time-varying variances and co-variances of cash and future prices are estimated by applying the Regime Switching Dynamic Correlations model (RSDC) from Pelletier (2006).[7] The RSDC model considers a K - multivariate time process:

$$Y_t = H_t^{1/2} U_t \quad \text{with } U_t \sim i.i.d.(0, I_K) \tag{13}$$

Where Y_t are the estimated (stationary) price series.

First DDGs, corn, soybean meal and grain sorghum are estimated for the two different time periods, to compare the difference in their dynamic correlations. Subsequently, estimations are made for DDGs, corn and soybean meal prices to compute the time-varying hedge ratios.

The time varying covariance matrix H_t to be estimated is decomposed into standard deviations and correlations, with different correlation values switching between different regimes through a Markov chain.

$$H_t \equiv S_t \Gamma_t S_t \tag{14}$$

where S_t is a Diagonal matrix with standard deviations: $s_{k,t}$ $k = 1 \ldots.. K$ and Γ_t is the correlations matrix

The standard deviations $s_{k,t}$ for each time series k – from the diagonal matrix S_t – are estimated via an ARMACH (1,1) model (Taylor, 1986). In the ARMACH model, the conditional standard deviations of each series k are:

$$s_t = \omega + \tilde{\alpha}|y_{t-1}| + \beta s_{t-1} \quad \text{with } \tilde{\alpha} = \alpha / E|\tilde{u}_t|\text{, for stationary purposes} \tag{15}$$

The correlation matrix Γ_t follows a Markov chain, with different values for different regimes, i.e. for some particular t periods it may be in one regime with a certain set of correlations, and for other particular t periods it may be in another regime, with a different set of correlations. The time-varying correlation matrix Γ_t is defined as:

[7] Application of the State Dependent Regime Switching Correlations model (Tejeda, Goodwin and Pelletier, 2009) is left for a future study.

$$\Gamma_t = \sum_{n=1}^{N} \mathbf{1}_{\{\Delta_t = n\}} \Gamma_n \qquad (11)$$

where Δ_t is an unobserved Markov chain process independent of U_t, taking N possible regimes or values ($\Delta_t = 1,2, \dots N$). And **1** is an indicator function. In this study two different correlation regimes are considered.[8] The 'probability law' governing the Markov chain process Δ_t is defined by its constant transition probability matrix Π_t, with elements of row i and column j: $\pi_t^{i,j}$, which is equivalent to the probability of going from regime *i* in period *t-1* to regime *j* in period *t.* The results are generated using Ox version 5.0 (Doornik, 2007) and parameter estimation is via maximum likelihood in two steps, with the assurance that the variance/covariance matrix remains PSD (positive semi-definite). First the standard deviations are obtained, and then the correlations are estimated. Further estimation details are in Pelletier (2006) and Tejeda et al. (2009).

Data

Weekly cash prices for corn are from Decatur-Central Illinois, for soybean meal (protein 46.5 to 48%) are from Central Illinois, for grain sorghum are from W.S. West Illinois (Springfield, IL), and for Distillers Dried Grains (10% moisture) are f.o.b. 30 day delivery from Central Illinois; all obtained from the USDA. These prices were purposely taken from Illinois to minimize spatial differences. The futures weekly prices for corn and soybean meal (48%) are from the CBOT, obtained through the Commodity Resource Bureau (CRB). Prices from futures contracts consider the nearest maturity contract, excluding the maturity month.

Prices are from August 26, 2000 through September 3, 2011, in accordance with USDA guidelines for marketing years and partitioned in two periods. The first period is from September

[8] Pelletier (2006) estimates up to three different regimes of dynamic correlations among four exchange rates, and finds that the likelihood ratio (LR) 'improvement' of a model with two regimes compared to that of three regimes is less than 1%. The downside being that there are many more parameters to be estimated.

2000 to August 2005, prior to the 2005 Energy Act. The second period considers prices from September 2004 up until August 2011. Figures 1 and 2 are charts of these prices for each respective period.

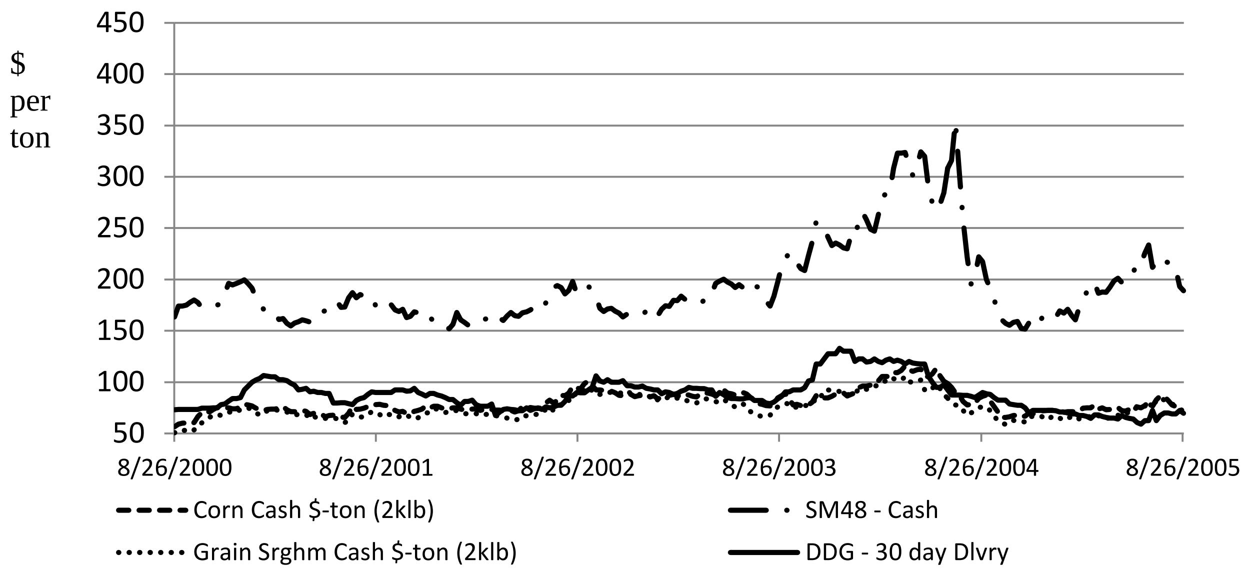

Figure 1. Corn, Soybean Meal, Grain Sorghum Spot Prices & DDGs 30 day delivery – September 2000 to August 2005.

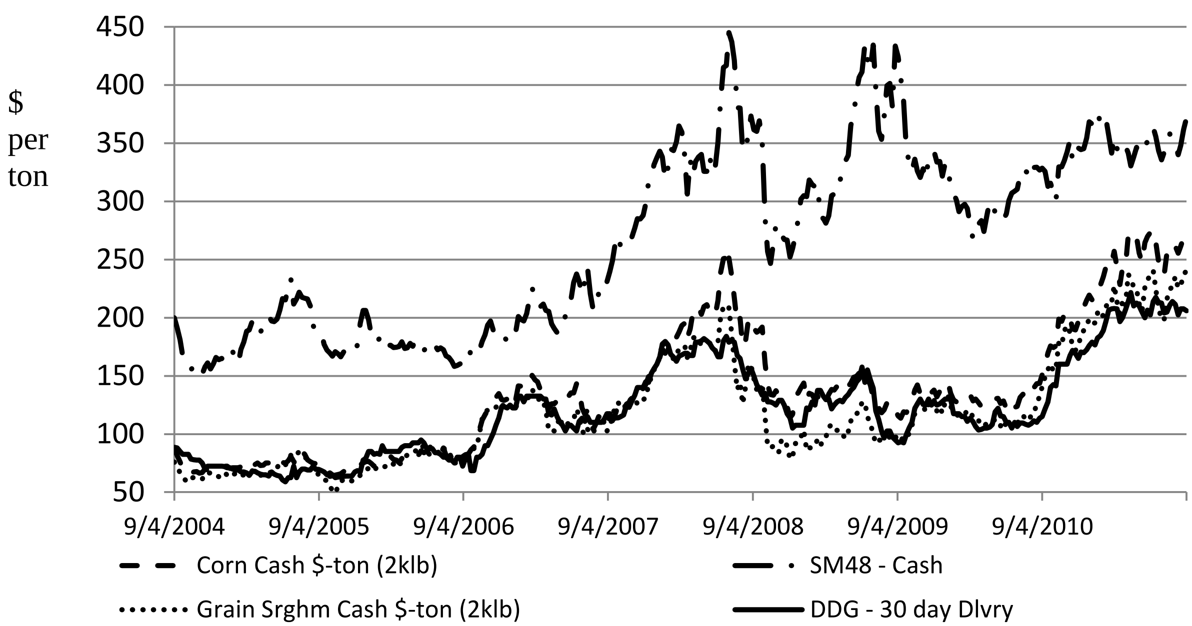

Figure 2. Corn, Soybean Meal, Grain Sorghum Spot Prices & DDGs 30 day delivery – September 2004 to August 2011.

Table 1 has summary statistics for each period and Table 2 contains summary statistics for corn and soybean meal futures

Table 1. Summary Statistics for Spot Prices ($/ton)

	September 2000 to August 2005				September 2004 to August 2011			
	Corn	Sybn Meal	Grn Srghm	DDG	Corn	Sybn Meal	Grn Srghm	DDG
Mean	80.41	194.20	75.11	87.82	136.29	269.58	119.30	120.95
Stnd. Dvtn	11.36	40.75	11.34	16.01	55.99	79.22	47.53	41.95
Max	115.71	353.75	105.36	133.00	275.18	445.00	241.25	221.50
Min	56.43	151.60	50.36	59.00	63.57	151.60	48.93	59.00

Table 2. Summary Statistics for Futures Prices ($/ton)

	September 2000 to August 2005		September 2004 to August 2011	
	Corn	Sybn Meal	Corn	Sybn Meal
Mean	81.65	187.08	124.12	249.60
Stnd. Dvtn	10.24	39.92	42.64	70.16
Max	118.03	336.00	274.20	445.92
Min	67.05	143.60	69.64	147.00

Results & Discussion

Unit root tests for non-stationarity were conducted on all cash and future price series by applying the Phillips-Perron test.[9] Every price level series – for each time period studied – was determined to have a unit root, thus affirming the use of price changes for the model being applied. The estimated dynamic correlations of the two periods considered (September 2000 to August 2005 and September 2004 to August 2011) where contrasted with the unconditional concurrent correlation obtained between DDGs and corn prices, and between DDGs and soybean meal prices. Results of the estimated dynamic correlations are in Table 3.

[9] Unit Root test from Phillips, P.C.B and P. Perron (1988), where the null hypothesis considers the series being non-stationary

For the first period, the dynamic correlations determined between DDGs and corn were 0.43205 at one regime and -0.0824 at the other regime. However, neither value was statistically significant. Thus both price series were dynamically changing in an uncorrelated manner. The unconditional concurrent correlation obtained for this period was -0.0036.

Table 3. Dynamic Correlations between DDGs, Corn, Soybean Meal and Grain Sorghum for Regime 1 and Regime 2

	Sept. 2000 to Aug. 2005	*Standard Error*	*Sept. 2004 to Aug. 2011*	*Standard Error*
Γ_1 - Correlation Regime 1				
DDGs – Corn	0.43025	0.5064	*0.40369**	0.1867
DDGs –Soybean Meal	0.37864	0.5375	*0.28327+*	0.1887
DDGs – Grain Sorghum	0.46880	0.4799	*0.38827**	0.1749
Corn - Soybean Meal	*0.58397***	0.3328	*0.72453**	0.0885
Corn - Grain Sorghum	0.55313	0.5605	*0.85794**	0.0302
Sybn Meal – Grn Sorghm	0.26309	1.0378	*0.60169**	0.0653
Γ_2 - Correlation Regime 2				
DDGs – Corn	-0.08240	0.1939	-0.03121	0.4529
DDGs –Soybean Meal	-0.12091	0.1717	-0.37812	0.3833
DDGs – Grain Sorghum	-0.08081	0.1749	-0.17016	0.5018
Corn - Soybean Meal	*0.36894**	0.1622	0.11306	0.5759
Corn - Grain Sorghum	*0.87735**	0.0451	*0.95086**	0.0275
Sybn Meal – Grn Sorghm	*0.39174**	0.1486	0.22720	0.5116
Probability Betas				
Prob11	*0.88219**	0.3708	*0.80961**	0.1067
Prob22	*0.96902**	0.0905	*0.53072**	0.6265

* Significant at 5% level or less
** Significant at 5% level or less
\+ Significant at 15% level or less

A similar result was determined for the dynamic correlations between DDGs and soybean meal for this first time period. The dynamic correlation at one regime was 0.37684 and at the other regime was -0.1209; yet once again these values were not significant. Hence again the evolution of changes in the two prices seem practically uncorrelated.[10] The unconditional correlation between the two series was 0.0458. Similar results of non-significant correlation were obtained between DDGs and grain sorghum for this period. The second period estimated had dynamic correlations that were statistically significant. In this sense, a significant ($p<0.05$) correlation of 0.4037 between DDGs and corn was estimated for one regime; yet, a non-significant correlation of -0.0312 was estimated for the other regime. Likewise, a mildly significant ($p<0.15$) correlation of 0.2833 between DDGs and soybean meal was obtained for one regime level; yet again a non-significant correlation of -0.3781 was estimated for the other regime. Comparison to the unconditional concurrent correlation between DDGs and corn at 0.2946, and between DDGs and soybean meal at 0.0934, respectively, are in Figures 3 and 4.

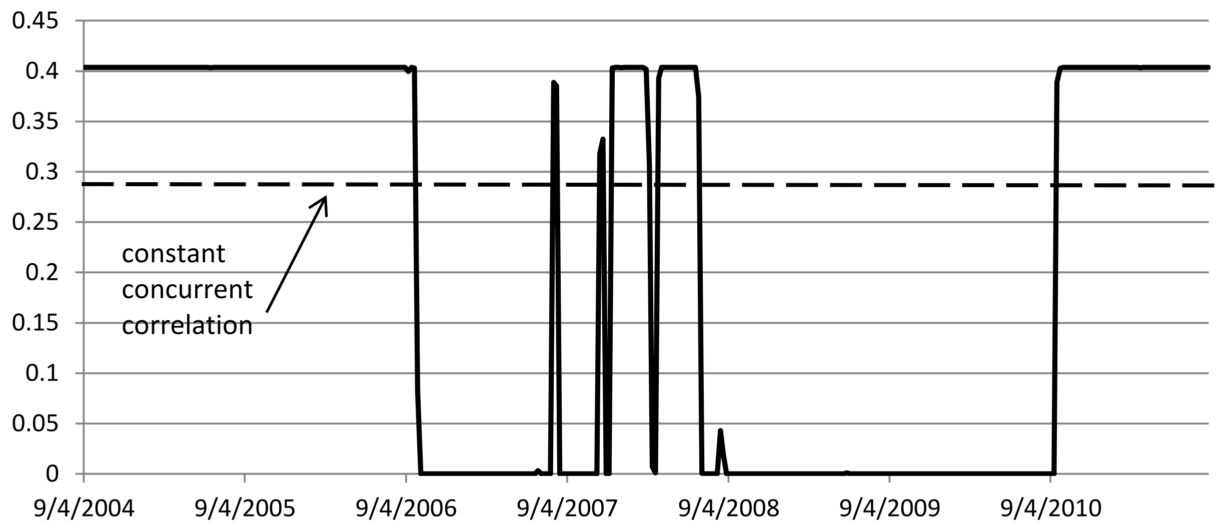

Figure 3. Dynamic Correlations between DDGs and Corn Price Changes – September 2004 to August 2011.

---

[10] A Johansen co-integration test is warranted to identify the extent to which the two markets may move together.

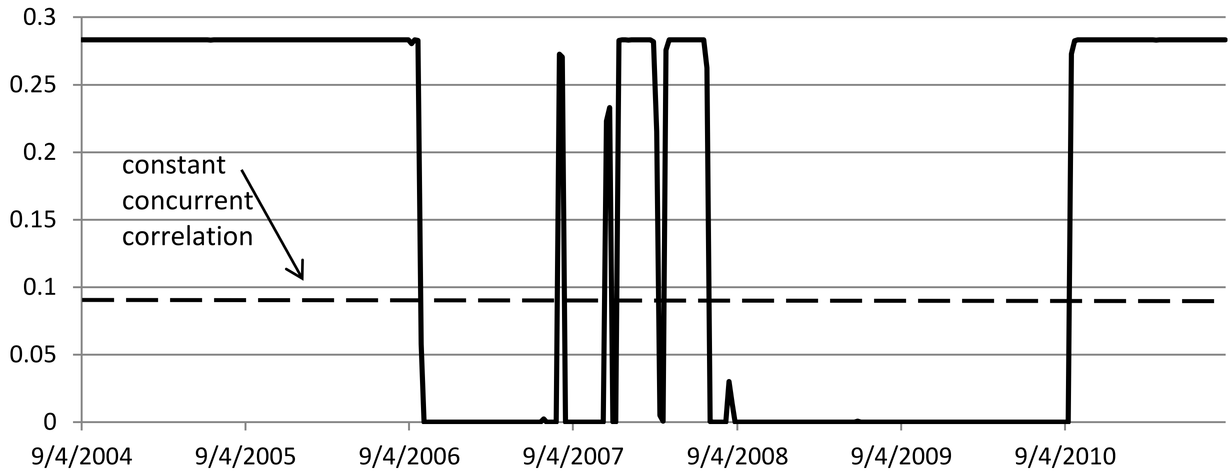

Figure 4. Dynamic Correlations between DDGs and Soybean Meal Price Changes – September 2004 to August 2011

Once again similar results were obtained between DDGs and grain sorghum. I.e., a positive significant ($p<0.05$) correlation of 0.388 at one regime; and yet a negative (-0.1702) non-significant value was obtained for the other regime. Hence a substantial impact, after the ethanol mandate, is identified by the dynamic effects of DDGs on corn, soybean meal and grain sorghum markets.

Regarding dynamic hedge ratios, these were estimated for the period between January 2005 and January 2011 (post ethanol mandate). The dynamic correlations between DDGs and Corn Futures, and between DDG's and Soybean Meal Futures, are in Table 4.

Table 4 Dynamic Correlations between DDGs Spot and Corn and Soybean Futures - Price Changes (4 weeks) - from January2005 to January 2011 (standard errors in parenthesis)

	DDGs & Corn	DDGs & Sybn Meal	Corn & Sybn Meal
Γ_1 - Regime 1	0.59083*	0.63807*	0.73751*
	(0.0824)	(0.0948)	(0.0567)
Γ_2 - Regime 2	-0.13274	-0.38142*	0.39082*
	(0.1620)	(0.1861)	(0.8010)

*Significant at 5% level or less

All correlations are statistically significant ($p<0.05$), except for DDGs and corn at the second regime. An unexpected result is that DDGs and soybean meal price changes have a period(s) (i.e. second regime) where they have an inverse (negative) relationship. This has an effect on the dynamic hedge ratios computed. The dynamic correlations varying through the time period are shown in Figures 5 and 6 and compared to the unconditional correlation of price changes, being 0.2482 between DDGs and corn, and 0.2409 between DDGs and soybean meal for this same period.

The Armach model estimates for these price (changes) series are in Table 5. In general, every price change had a significant parameter for both the absolute value of innovations and the prior standard deviation, except for DDGs that did not have the latter. The optimal average dynamic hedge ratios are in Table 6. As means of comparison, out-of-sample data from January 2011 to June 2011 is taken, and the optimal average hedge ratios are computed, with results in Table 7.

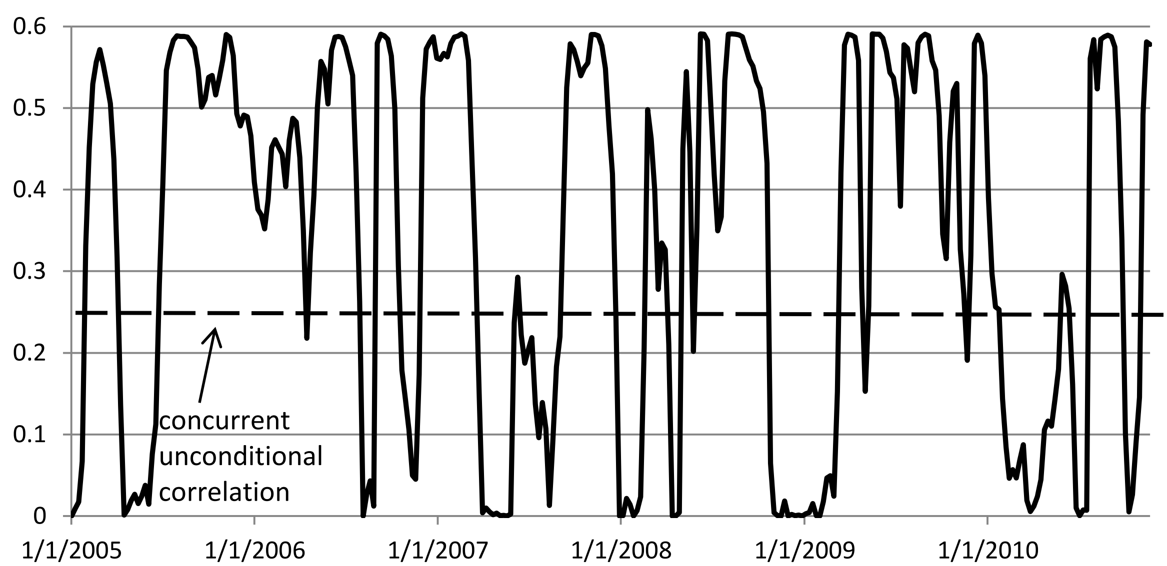

Figure 5. Dynamic Correlations between DDGs and Corn Futures Price Changes (4 weeks) – January 2005 to January 2011

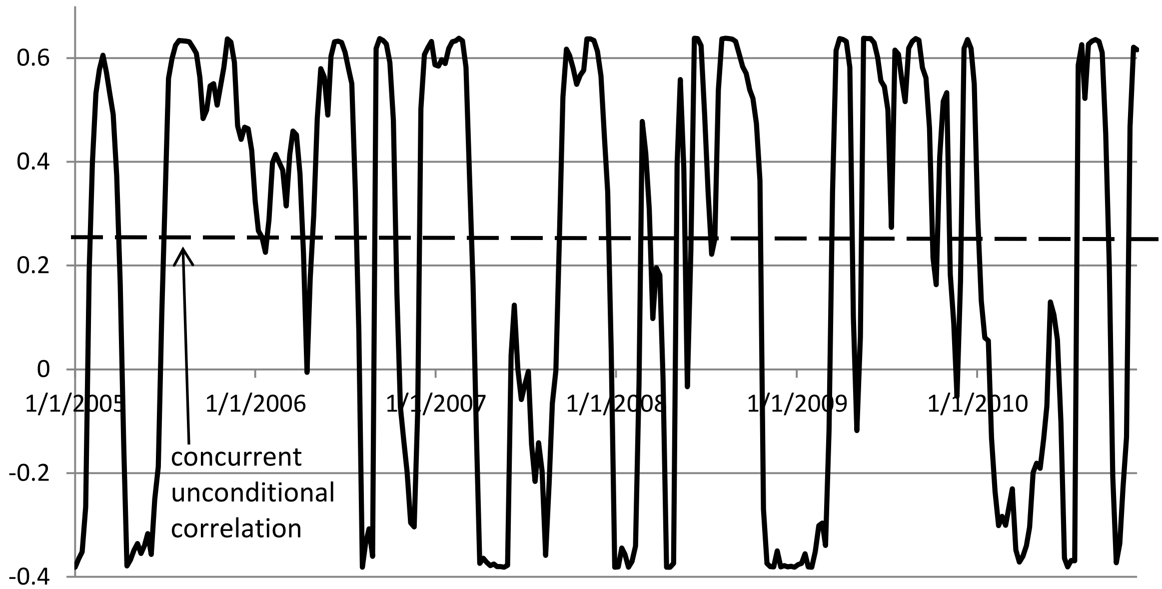

Figure 6. Dynamic Correlations between DDGs and Soybean Meal Futures Price Changes (4 weeks) – January 2005 to January 2011

Table 5. Armach parameter estimates for DDGs and Soybean Meal Futures Price Changes (4 weeks) – January 2005 to January 2011

	DDGs Cash	*Corn* Futures	*Soybean Meal* Futures
ω - omega	3.23817	1.44093	2.09553
	(5.7180)	(2.6760)	(4.9644)
α~ - alpha tilda	0.60236*	0.40144*	0.39845*
	(0.1724)	(0.2005)	(0.1678)
β - beta	0.16369	0.57957**	0.58829**
	(0.7475)	(0.3570)	(0.3660)

*Significance at 5% level or less **Significance at 10% level or less

Table 6. Average Time-Varying Hedge Ratio for Corn, Soybean Meal and Combination of Corn & Soybean Meal between January 2005 and January 2011 *(In-Sample)*

	Average Time-Varying Hedge Ratio *(In-Sample)*		
	Corn	*Soybean Meal*	*Corn & Soybean Meal*
Regime 1	0.31034	0.22769	0.13849 & 0.15831
Regime 2	0.0	-0.13611	0.09242 & -0.16065

Table 7. Average Time-Varying Hedge Ratio for Corn, Soybean Meal and Combination of Corn & Soybean Meal between January 2011 and June 2011 *(Out-of-Sample)*

	Average Time-Varying Hedge Ratio *(Out-of-Sample)*		
	Corn	*Soybean Meal*	*Corn & Soybean Meal*
Regime 1	0.23811	0.39148	0.10347 & 0.25364
Regime 2	0.0	-0.21808	0.06905 & -0.25739

Given the significant negative dynamic correlation for soybean meal and DDGs at the second regime (Table 4), there is likewise a negative mean time-varying hedge ratio for soybean meal at the second regime. This is obtained for both in and out-of-sample data. This result implies a long future contract instead of a short contract, when being at that regime. It is relevant to point out that the unit for these hedge ratios are one ton of a corn or soybean futures contract on a per ton of DDG basis. Thus there is a need to properly re-quantify the average optimal hedge ratios to "the number of tons of DDGs per actual number of corn and/or soybean contracts". Each corn futures contract is per 5,000 bushels or approximately 140 (short) tons of corn, and the soybean meal futures contract is per 100 tons of soybean meal.

In order to compare the cross-hedging effectiveness among the alternatives – either corn or soybean meal, or a mixture of corn and soybean meal – a factor equal to the percentage reduction in the variance of the hedged margin with respect to the un-hedged margin (Garcia, P., J. Roh, and R.M. Leuthold. 1995),[11] is computed. Once again out of sample data is used to corroborate the findings. Table 8 has results for in-sample data and Table 9 for out-of-sample data.

[11] This factor is equal to $1 - \frac{Var(hedged)}{Var(unhedged)}$

Table 8. Hedging Effectiveness between January 2005 and January 2011 *(In-Sample)*

	Model	Mean	Variance	Percent Reduction
	Un-hedged	0.9411	84.8339	
	Naive Corn	-0.4539	202.5612	-138.77
	Naive Soybean Meal	-1.0070	476.5054	-461.69
Simple	Corn			
	Regime 1	*0.1947*	*83.2468*	*1.87*
	Soybean Meal			
	Regime 1	0.0560	96.1521	-13.34
	Regime 2	1.4701	110.7947	-30.60
	Combined	*0.7189*	*48.3607*	*42.99*
	Naive Corn & Soybean Meal	-2.4020	1009.6976	-1090.21
RSDC	Corn & Soybean Meal			
	Regime 1	0.0389	88.4843	-4.30
	Regime 2	1.3433	108.1997	-27.54
	Combined	*0.8305*	*54.9224*	*35.26*

Table 9. Hedging Effectiveness between January 2011 and June 2011 *(Out-of-Sample)*

	Model	Mean	Variance	Percent Reduction
	Un-hedged	4.4773	112.6304	
	Naive Corn	-2.5438	332.5697	-195.28
	Naive Soybean Meal	4.5000	324.5952	-188.20
Simple	Corn			
	Regime 1	2.8225	135.5399	-20.34
	Soybean Meal			
	Regime 1	4.3076	199.7511	-77.35
	Regime 2	*4.5787*	*102.0177*	*9.42*
	Combined	*5.5509*	*70.7902*	*37.15*
	Naive Corn & Soybean Meal	-2.5211	650.7217	-477.75
RSDC	Corn & Soybean Meal			
	Regime 1	3.6209	178.5407	-58.52
	Regime 2	*4.1042*	*102.1889*	*9.27*
	Combined	*4.1009*	*71.2259*	*36.76*

For the in-sample data, only a small 1.9 percent of variance reduction is obtained by considering the time-varying hedge ratio of corn alone, in comparison to the un-hedged approach. However, this result does not hold for the out-of-sample data. As for the naive hedging strategies, all of them result in larger margin variations than that of the un-hedged one, thus not being preferred.

More favorable is the result of applying solely soybean meal time-varying hedge ratios, which decrease the margin's variation when applying a (minimum variation) combination of the hedge ratios obtained from both regimes. This result holds for both in and out-of sample data sets at, 43 and 37.15 percent, respectively. Furthermore, there is an improvement of applying a (minimum variation) combination of the mixture of time-varying corn and soybean hedge ratios obtained for both periods. This result once again holds for both sample data sets. However, the improvement obtained is a bit below the case of pure soybean meal time-varying hedge ratios.

In general, results show that there is a substantial improvement by using the time-varying correlations in comparison to the simple hedging model and the naive hedging method, for the post-ethanol mandated period. Application of different time-periods, other than four weeks between the cash position and liquidation of the futures contracts, may elucidate further the dynamic correlation between DDGs and soybean meal futures contracts for the post-ethanol mandated period. This takes special relevance given the significant periods of negative dynamic correlations between DDGs and soybean meal, which had an impact in the optimal dynamic hedge ratios. In addition, DDGs prices from other locations may have an effect, and need to be addressed in terms of their dynamic spatial correlation, among others.

Conclusion

The application of a time-varying correlations model to determine the dynamic effect of the substantial growth in Distillers Dried Grains (DDGs) supply – from ethanol corn consumption – on other feedstock markets (specifically corn, soybean meal and grain sorghum) is conducted. The initial estimated pre-ethanol mandate period shows that there are no dynamic effects from DDGs on these other feed markets. That is, weekly spot price changes between DDGs, corn, soybean meal and grain sorghum have no significant dynamic correlation. This is not the case for the post ethanol mandated period, where all four feeds have periods of positive dynamic correlation among their price changes. In effect, significant positive dynamic correlations among weekly price changes of DDGs and corn and soybean meal are identified between September 2004 and August 2011.

Subsequently, futures contracts of corn and soybean meal are tested for hedging DDGs spot prices during the post ethanol mandate period, given that it is here that these markets show significant dynamic correlations. Time-varying hedge ratios are estimated for an agent considering a four week hedge period, by using either corn or soybean meal futures or a mixture of both corn and soybean meal contracts. Results obtained may be counter-intuitive, as they follow from estimated periods of negative dynamic correlations between soybean meal and DDGs. Thus best optimal dynamic hedge ratios are from a 'combination' of the two estimated regime's dynamic hedge ratios for DDGs and soybean meal. Next optimal considers a mixture of corn and soybean meal contracts, likewise for a 'combination' of the optimal hedge ratios obtained from both regimes.

This application does not permit an agent's hedging position to be revised once set. Allowing this condition during further study may provide substantial improvement of the results.

References

Anderson, D., J.D. Anderson, J. Sawyer. 2008. "Impact of the Ethanol Boom on Livestock and Dairy Industries: What Are They Going To Eat?" *Journal of Agricultural and Applied Economics* 40: 573-579.

Brinker, A. J., J. L. Parcell, K.C. Dhuyvetter, and J. R. V. Franken. 2009. "Cross-Hedging Distillers Dried Using Corn and Soybeans Futures Markets", *Journal of Agribusiness,* 27: 1-15.

Benninga, S., Eldor, R., and Zilcha, I. (1984): "The Optimal Hedge Ratio in Unbiased Futures Markets," *The Journal of Futures Markets,* 4:155–159

Brorsen, B.W, D.W. Buck, S. R. Koontz. 1998. "Hedging Hard Red Winter Wheat: Kansas City versus Chicago" *Journal of Futures Markets* 18: 449-466.

Doornik, J.A. 2007. Object-Oriented Matrix Programming Using Ox, 3rd ed. London: Timberlake Consultants Press and Oxford: www.doornik.com.

Featherstone, A. M., and T. G. Baker. 1987. "An examination of farm sector real asset dynamics: 1910-85", *American Journal of Agricultural Economics,* 69, 532-546

Feed Outlook, (2009) *,FDS-09d,* Economic Research Service – USDA, April 13, 2009.

Garcia, P., J. Roh, and R.M. Leuthold. 1995. "Simultaneously Determined, Time Varying Hedge Ratios in the Soy Complex", *Applied Economics,* 27: 1127-1134

Goodwin, B. K., and T. C. Schroeder. 1991. "Price dynamics in International Wheat Markets", *Canadian Journal of Agricultural Economics,* 39, 237-254.

Goodwin, B. K. 1992. "Forecasting Cattle Prices in the Presence of Structural Change", *Southern Journal of Agricultural Economics,* 24, 11-22.

Goodwin, B.K., and N.E. Piggott. 2001. "Spatial Market Integration in the Presence of Threshold Effects", *American Journal of Agricultural Economics*, 83: 302-317

Haigh, M. S., and D.A. Bessler. 2004. "Causality and price discovery: An application of directed acyclic graphs". *Journal of Business,* 77, 1099–1121

Hoffman, L., A. Baker. 2010. "Market Issues and Prospects for U.S. Distiller's Grains: Supply, Use and Price Relationships." *Outlook Report FDS-10K-01*, U.S. Department of Agriculture, Economic Research Service, December.

Johnson, L. L. (1960): "The Theory of Hedging and Speculation in Commodity Futures," *Review of Economic Studies,* 27:139–51

Lawrence, J.D., J. Mintert, J.D. Anderson, and D. P. Anderson. 2008. "Feed Grains and Livestock: Impacts on Meat Supplies and Prices", *Choices* 23: 11-15.

Leuthold, R. M., J. C. Junkus, and J. E. Cordier. 1989. The Theory and Practice of Futures Markets. Lexington MA: Lexington Books.

Manfredo, M.R., P. Garcia, R.M. Leuthold. 2000. "Time-Varying Multiproduct Hedge Ratio estimation in the Soybean Complex: A Simplified Approach". Proceedings of the NCR-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management. Chicago, Illinois, April 17-18, 2000

Myers, R.J., and S.R. Thompson. 1989. "Generalized Optimal Hedge Ratio Estimation", *American Journal of Agricultural Economics,* 71, 858-868

Pelletier, D. 2006. "Regime Switching for Dynamics Correlations" *Journal of Econometrics* 131:445-473.

Perrin, R., and T.J. Klopfenstein. 2000. "Economic Impact of Feeding Wet Grain Processors' Byproducts in Nebraska." Research Bulletin 337, Agricultural Research Division, Institute of Agriculture and Natural Resources, University Of Nebraska - Lincoln.

Phillips, P. C. and Perron, P. 1988. "Testing for a Unit Root in Time Series Regression," *Biometrika*, 75, 335–346

Sanders, D.R., M.R. Manfredo. 2004. "Comparing hedging effectiveness:An application of the encompassing principle." *Journal of Agricultural and Resource Economics* 29: 31–44.

T. C. Schroeder, and B. K. Goodwin. 1992. "Regional Fed Cattle Price Dynamics", *Western Journal of Agricultural Economics,* 15, 111-122

Schroeder, T. C. 2009. "Distillers Grain Prices: Spatial Relationships, Arbitrage Opportunities & Risk Management", *North America Inst. for Beef Economic Research, Kansas State University Agricultural Experiment Station and Cooperative Extension Service.* May

Tejeda, H.A., B.K. Goodwin, and D. Pelletier. 2009. "A State Dependent Regime Switching Model of Dynamic Correlations", *Selected paper presented at the AAEA Annual meeting*, Milwaukee, WI., July 26-28.

Tejeda, H.A., and B.K. Goodwin. 2011. "Dynamic Price Relationships in the Grain and Cattle Markets, Pre and Post Ethanol Mandate", *Selected paper presented at the AAEA Annual meeting*, Pittsburgh, PA., July 24-26.

Tejeda, H.A., and B.K. Goodwin. 2011.b. "Testing the Performance of Multi-Product Optimal Hedging with Time-Varying Correlations in Storable and Non-storable Commodities". Proceedings of the NCCC-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management. Saint Louis, MO, April 18-19, 2011.

Vukina, T and J.L. Anderson. 1993. "A State Space Forecasting Approach to Optimal Intertemporal Cross-Hedging", *American Journal of Agricultural Economics*, 75: 416-424.