Identifying volatility spillover effects from ethanol on corn, soybean and cattle markets through a State Dependent Regime Switching Model of Dynamic Correlations

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This paper empirically determines the effect from increased corn usage for ethanol production in the evolution of the dynamic relationships between corn, soybean, feeder cattle and live cattle markets - being corn and soybean major feed components – and contrasts results to a prior period when these markets did not face a surge in corn demand from ethanol production. A multivariate time-series model with dynamic correlations - based on a regime switching model with constant transition probabilities (Pelletier, 2006) that is extended to a model with state dependent transition probabilities - is applied to these grain and cattle markets. The model identifies asymmetric correlations between the markets, yet more importantly, the extended structure captures friction and spillover effects, specifically during the recent post-ethanol mandated corn consumption period. By incorporating state dependent transition probabilities in the regime switching process, the extended model permits the identification of underlying fundamentals affecting the dynamic correlations of markets. Identified significant fundamentals during the post-ethanol mandated period are the ratio of soybean to corn harvest price and corn's 'use to stock' ratio. The model incorporating corn 'use to stock' ratio as the variable in the state dependent transition probabilities is mildly preferred over the model with the ratio of soybean to corn harvest price, but is strongly preferred to a model with constant transition probabilities. Specific periods of risk spillovers from one market to another are identified during this post-ethanol period and their impacts on market interrelationships are discussed. Implications for agricultural price levels and risk, and related management policies are also discussed.

Introduction

Grain market prices sharply increased from 2006 until mid-2008 – approximately two-fold in the case of corn, and also rose steeply for soybeans. This may have impacted livestock markets by increasing prices and leading to significant volatility shocks, since more than half of the corn production is used as animal feed and soybeans remain an important feed source. High price levels and the magnitude of sustained high volatilities raise concerns for many sectors of the economy – consumers may face higher food prices, and producers face unprecedented levels of price uncertainty coupled with higher input prices. Policy makers seek to analyze the interrelationships among these markets and the effects of energy market shocks on agricultural markets. Figures 1.1, 1.2, 1.3 and 1.4 include time series charts of futures prices for corn, soybeans, feeder cattle and live or fed cattle, respectively. Likewise, figures 2.1, 2.2, 2.3 and 2.4 include times series charts of historical volatilities for these same commodities. Finally, figures, 3.1, 3.2., 3.3, 3.4 include times series charts of implied volatilities[1] for these same commodities.

Increasing grain commodity prices coupled with changes in their volatility has implications for many decision makers. A study by Goodwin and Kastens (1993) found that prices are by far the main source of risk for production decision-making. Crop producers are influenced in their planting decision making by having to decide between corn and/or soybean - seeking higher profitability – while taking into account higher input costs for corn production than for soybeans. At the same time, livestock producers require these crops as inputs and thus their costs and profitability are directly affected by the level and volatility in these prices. These agents may benefit from appropriate determination of the dynamic interrelationships among these markets, as this may lead to efficiency gains in their operation. Likewise, policy makers need to determine

[1] Data obtained from Commodity Resource Bureau (CRB) data

the impact that recent energy policies, in this case directly affecting corn consumption, have on prices and markets related to this grain.

This paper makes use of a newly developed extension of a multivariate time-series model, and determines dynamic market linkages and interrelationships between corn, soybean and feeder and fed cattle prices. The impact of the surge in corn usage for ethanol production in the evolution of these prices is empirically identified. A structure capturing friction between markets is incorporated in a multivariate time series model – an extension to the regime switching dynamic correlations model of Pelletier (2006) - to determine asymmetric correlations between grains and livestock prices, but more importantly to capture volatility spillovers. These spillovers are characterized by the persistence of markets remaining at certain correlation levels instead of switching to a different correlation regime. In addition, a potential lack of price transmission between markets is identified, which may occur as a result of adjustment costs between these markets.

Dynamic correlations among corn, soybeans and feeder and fed cattle markets are estimated for two separate periods - including the latest period when corn faced a consumption boost from ethanol production. Results of this latter period are compared to the previous period where corn, soybean and cattle production did not face the increased corn demand from ethanol production – mandated by the Energy Policy Acts of 2005 and 2007. Figure 4 depicts the corn consumption used in ethanol production through the past years.

The impact of significant underlying fundamental factor(s) are identified by specifically incorporating the 'use to stocks' ratio of corn – which comprises the market's dynamic demand and supply conditions for corn – into the evolution of the multiple prices. In addition, the ratio of soybeans to corn futures' harvest prices - which is a proportion contemplated by crop producers when deciding their planting acreage - is likewise incorporated in the dynamic process. Both of these factors, described in more detail below, have a role in spillover effects among the markets. Two different models are estimated – a restricted or parsimonious version and the full unrestricted version. Similar results are obtained from both models.

The paper proceeds by providing a general review of the relationship between corn and ethanol, then describes the characteristics of grain markets, and details the particular context of the corn market. A brief literature review of studies that have considered the impact of corn used for livestock feed on cattle profitability is subsequently provided. Likewise, previous studies regarding market linkages and price transmission, including asymmetric price adjustments in different cattle and pork markets are addressed. Subsequently, the two versions of the Regime Switching Dynamic Correlations model from Pelletier (2006) are presented – a parsimonious model and an unrestricted model – which estimate correlations at different regime levels for the markets considered. Two correlation regimes are taken into account in each model.

The parsimonious model considers each pair of markets having correlations of equal proportion between regimes, permitting less parameter estimation. Estimated results between the parsimonious and unrestricted model are fairly similar as anticipated, though the unrestricted model has some minor differences that will be discussed. Implications for how these commodity markets are linked to one another are discussed. Risk spillovers from one market to another are identified, and their impacts on market interrelationships are discussed.

Background

The relation between ethanol fuel production and use of agricultural commodities in the U.S., specifically in the case of corn, began regularly in the early 1900’s (with the model T from Ford). However ethanol production was strengthened after The Energy Tax Act of 1978, which provided an exemption on the federal excise tax (i.e., subsidy) of 40 cents per gallon of ethanol mixed with gasoline of up to 10% of ethanol content. Ethanol served as an oxygenate agent in the mix of gasoline production, trailing MTBE (Methyl Tertiary Butyl Ether) made from natural gas and petroleum. In 2004, this latter component had been banned from almost all states, since the EPA declared in 2000 that it constituted a ground-water pollutant.

Ethanol faced a rise in demand from the previous MTBE ban and likewise from the Energy Policy Act of 2005, mandating an increase in the use of renewable fuel energy – mainly ethanol. The Act called for a doubling of ethanol use by 2012. In 2007 Congress passed the Energy Independence and Security Act, which augmented the Renewable Fuels Standard to require that 36 billion gallons of ethanol and other fuels be blended into gasoline, diesel, and jet fuel by 2022. Ethanol production at the end of 2009 was about 10.7 billion gallons per year and is mandated to reach 13 billion gallons by 2012 and 15 billion gallons by 2015. This vast increase in ethanol production from corn in recent years has led to hikes in corn prices and acreage. Corn production land has been taken from soybean production, since these crops share similar production conditions. This has consequently lowered soybean production, causing an increase in soybean prices. A record use of corn acreage leading to a record harvest output was obtained in 2007. In 2008 a slight drop in corn acreage in favor of soybean production occurred. The following figure 5 presents time series for corn and soybean acreage in the United States.

Three characteristics distinguish grain commodity markets over that of other commodities (Schnepf, 2006). There is seasonality inherent in the production period. That is, crop producers make their production decisions based on ex-ante information or expectations about their anticipated yield, and thus considering the prices of the inputs as well as of the harvested crop. A second characteristic considers demand for these grains generally being of derived nature. i.e., a majority of the grains may be used as input for processing a different final product. In this study, more than half of the total corn production is used as major feed component for livestock. Finally, the nature of supply and demand is generally price-inelastic, especially for grains. That is, small movements in supply generate large price swings.

With respect to corn, the U.S., China, and Brazil account for two-thirds of the world's production. Of the three, the U.S. is the largest exporter, covering approximately two-thirds share of the world market with about 18% of its production. Since 2000, approximately 58% of the U.S. corn production has been used as the primary energy source of feed for livestock. The remaining 24% of corn production is used for food and industrial products such as starch, sweetener, fuel ethanol, corn oil and others.

With data from the Foreign Agricultural Service of the USDA, Westhoff (2008) notes that between the marketing years of 2005/2006 and 2007/2008, there was a rise of 35 million tons in U.S. corn consumption attributed to ethanol production. This accounted for approximately 43 percent of the increase in total world grain consumption, which if excluded, would have grown around 2 to 2.5 percent (i.e. very similar to world population growth). Prior to 2005, there had been a regular average increase of around 2 percent in total world grain consumption dating back to 2000. Recent hikes in corn consumption beyond this rate of world population growth may be attributable to use for production of ethanol (figure 4).

Corn is the most broadly produced feed grain in the U.S., encompassing more than 50 percent of the total value and production of all feed grains. Corn feed competes with other feed grains – grain sorghum or 'milo', barley and oats, as well as feed wheat. Other feed ration components are roughage - which may consist of alfalfa, prairie hay, or corn silage among others and the protein component consisting of soybean (soybean meal), and cotton meal among others. In general, the largest feed component is grain, led by roughage and a small amount of protein supplements. However, the choice of rations also depends upon the relative prices among the feed components in line with feed grain markets being sensitive to relative prices among the different feed components.

Cattle producers take feeder or calf cattle and feed them with a high energy diet during a period of four to six months in order to rapidly increase their weight and sell for slaughter meat. These producers operate feedlots, which may be either small home feedlot operations, with less than 1,000 heads, or large commercial feedlot operations with up to 50,000 heads. In 2004, commercial feedlots were only about 11 percent of total number of feedlots in the U.S. However, these commercial feedlots provided about 85 percent of the market's fed cattle. In order to maximize profit, these feedlots are responsive to price changes of feed components.

The 2005 Energy Policy Act, and subsequently the 2007 Energy Independence and Security Act resulted in a substantial rise in the demand for corn (Westhoff, 2008). These policies produced an outward shift of corn demand – main input for ethanol production, resulting in a larger corn supply at a higher price. This increased corn production affected the soybean market, which shares a common geographical production area with corn, by transferring acreage to corn. The lower supply of soybeans resulted in a higher soybean price. Likewise, both crops serve as feed for livestock markets, potentially affecting the price and profitability of these markets.

Charts depicting this relationship between demand and supply for corn and for soybeans are in figures 6.1 and 6.2, respectively. Price elasticity of corn supply becomes more inelastic given the outward shift in corn demand due to increased consumption from ethanol production, thus raising corn's price and its quantity consumed. In addition, the price elasticity of demand for soybean also becomes more inelastic given the inward shift in its supply due to acreage transfer from soybean to corn production; thus resulting in a higher price yet lower consumption.

A study of the dynamic effects that these supply and demand factors for corn and soybean have on the price variations of grain and cattle markets – corn, soybean, feeder cattle and live cattle, is done by specifically taking into account the impact of the global supply and demand conditions for corn. In line with previous studies (Goodwin and Schnepf, 2000 and Goodwin et al., 2005), a factor considering the dynamic demand and supply from corn, noted as the corn 'use to stock' ratio, is incorporated in the evolution of the dynamic process.

In addition, the effect from the ratio of soybean to corn harvest price is likewise taken into account in the dynamic price variations of grain and cattle markets, since this ratio is a factor that producers consider during the crop planting stage. Each year corn and/or soybean producers assess their acreage decision for the next season following the current harvest period. For their decision, producers consider a ratio of the harvest prices for soybeans and corn to be around 2.2 to 2.4 - equal to a Break Even Price Ratio (BEPR). [2] For these values, producers do not favor production of one crop over the other. This BEPR ratio takes into consideration input requirements for each grain, as well as their different yield per acre, and other related expenses (Lin & Riley, 1998). The harvest period prices are December contracts for corn and November contracts for soybean. The ratio is checked by producers prior to the planting season (i.e. during December – March). A substantial change in the ratio's value may modify a producers' planting decision. e.g., the producer plants corn instead of the initial plan for soybean if the ratio is lower than two.

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[2] BEPR is the ratio of expected soybeans-to-corn price ratio which equates the expected net returns of producing corn and soybeans, given trend yields of corn and soybeans, the expected price of corn, the variable costs of corn and soybean production, the expected program payments and other program expenses. (Lin & Riley 1998).

Another aspect addressed in this paper refers to market linkage and price transmission between grains and cattle markets being subject to certain transaction costs. These transaction or adjustment costs may respond to information and/or negotiation costs (Hobbs, 1997), as in the case of cattle producing agents selling slaughter cattle in different market channels (i.e. at auctions or by contract directly to a packer). The adjustment cost here may result in price variations not being transmitted at all between the markets. e.g., grain and live cattle markets. Transaction costs between other markets may result in instances where price variations are not passed on directly, but are likewise subject to certain adjustment costs.

Literature Review

Numerous studies have addressed the effect of corn prices on livestock profitability, since it is their main source of feed. In cattle production profitability, a study by Langemeier et al. (1992) concluded that in addition to cattle feeder and cattle fed (live cattle) prices, changes in corn prices had an approximate 22 percent impact in the variability of profits. Another study by Schroeder et al. (1993) found that corn price changes accounted for between 16 percent and 6 percent of cattle profit risk - decreasing the risk level as cattle placement weight increased (i.e. an increasing weight of the feeder cattle). A study by Mark et al. (2000) for cattle profitability obtained similar results.

Lawrence et al. (1999) found that corn prices, while still significant for cattle production profitability, had less impact than feed efficiency and average daily gain. Albright et al. (1994) specifically determined that about 60 percent of the variability in the cost of weight gain (i.e. feed efficiency) could be attributed to corn price variability.

A different study by Anderson and Trapp (2000) for the feeder cattle market, estimated a dynamic corn price ‘multiplier’ that simultaneously impacts placement weight, slaughter weight and feed-conversion rate as the price of corn changes. Results indicate that increases in corn prices are mitigated by changes in feeding composition or programs, producing a smaller decline of calf-feed prices than in a static analysis scenario. In other words, increased corn prices lead to a reduction of calf-feeder prices to maintain cattle production profitability, yet the reduction in these prices is diminished by changing feed rations.

A recent paper by Belasco et al. (2009) studied the dynamic relationships between cattle production yield risk factors, including the influence of cattle pen characteristics, with respect to the risks borne by cattle producer's profits by using a dynamic multivariate regression model. The price of feed, including corn, may be indirectly considered as part of a yield risk factor (dry matter feed conversion & average daily gain – i.e. 'cost' of gain) and the dynamic effect of this factor is estimated. In addition, Lawrence et al. (2008) refers to a monthly survey of commercial cattle feedlots by Kansas State University, which emphasizes that the cost of gain had risen from an approximate average of 54 cents per lb. in 2006 to 74 cents in 2007, to over 80 cents in 2008.

Regarding the sharp increase in grains such as corn and soybeans, especially from 2006 to 2008 - an extensive report detailing major factors was presented by Trostle (2008). In the report he states that recent global increases in demand of feedstock for biofuel – mentioned previously with respect to ethanol, along with a decline in the U.S. exchange rate have been relevant demand factors contributing to a hike in commodity prices. In addition supply factors such as increasing energy prices as crude oil prices rise, higher input production costs, and adverse weather have also contributed. Another report by Schnepf (2008) also contends that coarse grains – mainly corn though also barley, sorghum, oats and rye, have faced increased demand due to two major factors. One factor is feed use for livestock due to increased demand for meat from

India and China[3] (as these two large countries experience high income growth during this latest period). A larger factor is due to increased demand from input for biofuel production rising from policy mandates, both here in the U.S. as well as in Europe.

Markets may respond to transmission of price variations by fully passing them along, or by having adjustments according to transaction costs that are present between the markets. In some instances these markets may be related production wise, as in the case of corn and soybeans in the U.S. In other cases, these markets may be vertically related, as in the case of corn being main feed component for cattle production and soybean being an important protein feed component.

Several studies have been conducted regarding asymmetric price adjustments, including threshold behavior. A paper by Goodwin and Holt (1999) analyzed the dynamic relationship and transmission of market prices among marketing channels in the beef sector using a threshold error correction model accounting for the non-stationary nature of the prices and considered the asymmetric effects produced. Threshold behavior was found with the existence of two dynamic regimes. Additionally, and in response to price shocks, lags were found during the adjustment period between each market channel. A subsequent study by Goodwin and Harper (2000) for the pork sector arrived at similar results. Earlier papers by Boyd and Brorsen (1985) and Hahn (1990) also found significant lags during price adjustment. Another paper by Boyd and Brorsen (1988) found symmetric responses to price changes. However, Hahn (1990) found asymmetric responses to price changes in the different market channels.

Goodwin and Piggott (2001) studied market integration in spatially separate regional grain markets, through price linkages. Their analysis included thresholds that account for transaction costs, which delay price adjustments. Their results indicated that the markets are well integrated, and confirm the existence of threshold points for price adjustments. The speed of adjustment for

[3] This translates into competition for acreage between corn and soybean.

prices is higher than when the thresholds are not considered. A paper by Meyer and von Cramon-Taubedel (2004) conducts an extensive survey regarding asymmetric price transmission.

Method Overview

The empirical analysis uses an extended version of the Regime Switching Dynamics Correlation model (RSDC) of Pelletier (2006). Both models of the original RSDC are extended by modifying the transition probabilities that govern the switch between correlation regimes, from constant to state dependent probabilities. State dependent transition probabilities enable to identify the impact of underlying fundamental factors (e.g. indexes and/or prices) affecting the evolution of these dynamic correlations.

Two cases of state dependent transition probabilities, which include a weakly exogenous factor or variable, are contrasted. One case incorporates the dynamic ratio of 'use to stocks' for corn and the other case the ratio of soybeans to corn futures prices, with delivery in November and December, respectively. The initial case with a constant transition probability for switching between regimes is a nested case within the estimated models.

Data

Weekly averages of future prices for corn, soybean, feeder cattle and live cattle from the Chicago Board of Trade (CBOT) and Chicago Mercantile Exchange (CMEX) respectively are applied. These weekly average prices consider the nearest/closest maturity delivery date. Prices are from September 1998 until August 2008, and the periods between these months (September to the following August) are taken as a crop year, in conformity with USDA guidelines.

The product of one hundred times the difference of the log values of these prices[4] is considered. Three different scenarios are estimated to determine the effect of the surge in corn consumption due to ethanol mandated production. The first base scenario considers the entire

[4] 100*ln(P_t/P_{t-1})

data series previously mentioned, that is from September 1998 till end of August 2008. The next two scenarios considered are partitioned such that one series runs up till previous the energy acts, that is from September 1998 to August 2004. The other series considers data from September 2003 till August 2008. The two partitioned periods have an overlap of the crop year 2004, which experienced unusual volatility, in order to minimize potential different seasonality effects that may be present in one of the partitioned series versus the other. Summary statistics for the three scenarios of futures prices are in table 1, and their returns are in table 2.

The two different of cases weakly exogenous variables considered are in figures 7.1 and 7.2 for the entire period from 1998 to 2008. Data for the ‘use to stock’ ratio of corn was obtained from the monthly World Agricultural Supply and Demand Estimates (WASDE) reports at the USDA, using a similar method as that by Goodwin and Schnepf (2000). That is, the monthly data had a cubic spline interpolation method applied, converting it into weekly data for subsequent computation of a weekly corn ‘use to stock’ ratio.

Additionally, lagged values of the previous two weakly exogenous variables were considered for two weeks, one month, three months, six months, one year. However, model estimation with these variables did not present significant changes in the results. (i.e., each weakly exogenous variable for further lagged periods was statistically insignificant).

Summarizing, three different time period scenarios are estimated for three different *cases*:

i. the *nested case* (i.e. $x_{t-1} = 0$) for a constant transition probability.

ii. the *case with lagged ‘use to stock’ ratio of corn* as a weakly exogenous variable in the state dependent transition probability.

iii. the *case with lagged ratio of soybeans harvest price to corn harvest price* as a weakly exogenous variable in the state dependent transition probability.

Econometric Model:

RSDC model

Dynamic co-variances between series are partitioned into standard deviations and correlations, with correlations switching between different regime values through a Markov chain.

Consider a K - multivariate time series process,

(1) $$Y_t = H_t^{1/2} U_t$$

where $U_t \sim i.i.d.(0, I_K)$, Y_t may be a filtered (stationary) process and I_K is an identity matrix.

The time varying covariance matrix H_t is decomposed into standard deviations and correlations:

(2) $$H_t \equiv S_t \Gamma_t S_t$$

where S_t is a Diagonal matrix with standard deviations: $s_{k,t}$, $k = 1 \ldots\ldots K$, and Γ_t is the correlations matrix. This decomposition of covariance matrix has been previously used by Bollerslev (1990), Tse & Tsui (2002), Engle (2002), and Pelletier (2006).

The standard deviations $s_{k,t}$ for each time series k - from the diagonal matrix S_t, are assumed to follow an ARMACH model (Taylor, 1986) defined below. The correlation matrix Γ_t follows a Markov chain, with different correlations for different regimes.

Markov Process for Regime Switching between Correlations:

The RSDC model considers multiple series transitioning between regimes of different correlations according to a latent Markov chain process. The switch from one regime to another is governed by transition probabilities. The time-varying correlation matrix Γ_t is defined similarly to Pelletier (2006):

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

where Δ_t is an unobserved Markov chain process independent of U_t, taking N possible regimes or values ($\Delta_t = 1,2, \ldots N$). And **1** is an indicator function for each regime. The $K \ x \ K$ matrices

Γ_n are correlation matrices - symmetric, positive semi-definite (PSD), ones on the diagonal, off-diagonal elements between values of -1 and 1, with $\Gamma_n \neq \Gamma_{n'}$ for $n \neq n'$. The 'probability law' governing the Markov chain process Δ_t is defined by its state dependent transition probability matrix: Π_t. The probability of going from regime i in period $t-1$ to regime j in period t is denoted by $\pi_t^{i,j}$, i.e. $\pi_t^{i,j} = P(\Delta_t = j | \Delta_{t-1} = i)$. The matrix Π_t has elements of row i and column j. The Markov chain satisfies the standard assumptions. That is - aperiodic[5], irreducible[6] and ergodic[7] (Ross, 1993). The limiting probability of being in regime n is π^n, as per the ergodic property of a Markov chain.

Restricted Model

The parsimonious or restricted model for the time-varying correlation matrix Γ_t is as follows and similar to Pelletier (2006):

(2.2) $$\Gamma_t = \Gamma\lambda(\Delta_t) + I_K\big(1 - \lambda(\Delta_t)\big)$$

with Γ being a fixed KxK correlation matrix for all states or regimes considered, I_K is a KxK identity matrix, and $\lambda(\Delta_t)\ \epsilon\ [0,1]$ is a univariate random process governed by an unobserved Markov chain process Δ_t that takes N possible values ($\Delta_t = 1,2 \ldots N$) being independent of U_t.

The correlation matrix at time t (i.e., Γ_t) is a weighted average of two extreme states or regimes – uncorrelated returns at $\lambda(\Delta_t) = 0$, or highly correlated returns at $\lambda(\Delta_t) = 1$. Change among correlations of different regimes are strictly proportional to $\lambda(\Delta_t)$, and the diagonals (own-correlations) are left at one.

[5] An aperiodic process is one that does not return to a certain state i within a definite, known, number of time steps (i.e. returns to a certain state i can occur at any irregular time steps).
[6] An irreducible process is one that has the possibility to arrive at any state from previously being at any state, i.e. there is no limitation to access any certain state when coming from any specific state.
[7] An ergodic state is one that is aperiodic and positive recurrent. This latter refers to a state having a finite expected return time to state i, from previously being at state i., i.e. it will return at some point to state i with a finite expected return time.

Univariate Model

The time-varying standard deviations are modeled directly by using the ARMACH process from Taylor (1986). In ARMACH, the conditional standard deviation (s_t) follows:

(2.3) $$s_t{}^{8} = \omega + \sum_{i=1}^{q} \tilde{\alpha}_i \, |y_{t-i}| + \sum_{j=1}^{p} \beta_j \, s_{t-j}$$

with $\tilde{\alpha}_i{}^{9} = \alpha_i / E|\tilde{u}_t|$, for stationary purposes.

State Dependent, Time-varying Probabilities

State dependent time-varying transition probabilities within regimes are introduced with a procedure from Diebold et al. (1994). As noted, two regime switching models will be extended. First is the parsimonious (restricted) model (2.2) and the second is the unrestricted model (2.1).

The state dependent probability matrix Π_t has elements of row i and column j:

$$\pi_t^{i,i} = P(\Delta_t = i \mid \Delta_{t-1} = i \,, x_{t-1}; \beta_i) = \frac{\exp(x_{t-1}^{'}\beta_i)}{1+\exp(x_{t-1}^{'}\beta_i)}$$

$$\pi_t^{i,j} = P(\Delta_t = j \mid \Delta_{t-1} = i \,, x_{t-1}; \beta_i) = 1 - \frac{\exp(x_{t-1}^{'}\beta_i)}{1+\exp(x_{t-1}^{'}\beta_i)}$$

For the specific case of considering two regimes or two states: e.g. $\Delta_t = 1$, i.e. being at regime number 1 or $\Delta_t = 2$, i.e. being at regime number 2; and for variables x_{t-1} being weakly exogenous variables, the transition probability matrix Π_t is presented below.

[8] Conditional Standard Deviation: s_t, where $\tilde{\alpha}_i$ is the parameter for the series' previous $(t-i)$ observations (or innovation), and β_j is the parameter for the previous $(t-j)$ standard deviations. As mentioned previously since the expectation enters as a linear operator, ARMACH provides ease of use for multi-step ahead computation of conditional expectations.

[9] $\tilde{\alpha}_i = \alpha_i / E|\tilde{u}_t|$ comes from computing the Un-conditional s_t, i.e. $E(s_t)$, and thus assuring s_t of being stationary.

(3) Transition probability matrix Π_t

Time t

Time t-1	**State 1**	**State 2**
State 1	π_t^{11} $P(\Delta_t = 1 \mid \Delta_{t-1} = 1, x_{t-1}; \gamma_1)$ $= \frac{\exp(x_{t-1}^{'}\gamma_1)}{1+\exp(x_{t-1}^{'}\gamma_1)}$	$\pi_t^{12} = (1 - \pi_t^{11})$ $P(\Delta_t = 2 \mid \Delta_{t-1} = 1, x_{t-1}; \gamma_1)$ $= 1 - \frac{\exp(x_{t-1}^{'}\gamma_1)}{1+\exp(x_{t-1}^{'}\gamma_1)}$
State 2	$\pi_t^{21} = (1 - \pi_t^{22})$ $P(\Delta_t = 1 \mid \Delta_{t-1} = 2, x_{t-1}; \gamma_2)$ $= 1 - \frac{\exp(x_{t-1}^{'}\gamma_2)}{1+\exp(x_{t-1}^{'}\gamma_2)}$	π_t^{22} $P(\Delta_t = 2 \mid \Delta_{t-1} = 2, x_{t-1}; \gamma_2)$ $= \frac{\exp(x_{t-1}^{'}\gamma_2)}{1+\exp(x_{t-1}^{'}\gamma_2)}$

where $x_{t-1} = (1, x_{1,t-1}, \ldots.., x_{(m-1),t-1})'$ & γ_i[10] $= (\gamma_{i1}, \gamma_{i2}, \ldots \ldots \ldots, \gamma_{i(m-1)}), i = 1 \text{ or } 2;$

Friction level

Persistence of the dynamic correlations in the Markov chain may vary as a function of the underlying fundamental variable introduced in the regime switching transition probability. Thus friction is identified when it holds the series in a particular regime instead of switching these to a different correlation regime, had the related fundamental factor not been taken into account. This type of friction may appear for example as a consequence of the unusual steady increase or decrease of the fundamental underlying market factor such as price ratios, stock levels or industry specific indices or ratios. These factors are explicitly incorporated as a weakly exogenous variable in the transition probabilities between regimes.

[10] Here we use $\gamma_i$the same as β_i of previous general probability definition in order to differentiate from the β_j parameter for the lagged standard deviation (s_{t-j}) to be estimated for the ARMACH model (2.3).

Conversely, the incorporated fundamental variable may favor the switch from one regime to another regime at a particular period during the evolution of the series. This regime change - in response to the effect of the fundamental variable - is contrasted to the case where the factor had not been considered because of constant transition probabilities (i.e., this latter case may not have had a regime switch at that particular period). Thus the new or 'switched to' correlation may be more representative of the real dynamic process – by taking into account the fundamental variable - in comparison to the case of unaccounted factors. This identified factor becomes the opposite of a friction and may be considered a facilitator.

The friction levels and their degree extent are a function of the weakly exogenous fundamental variables x_{t-1} and their coefficients β_i (or γ_i) for the different regimes estimated. Two correlation regimes are estimated in our dynamic correlations model and for simplicity only one weakly exogenous variable, besides the constant factor, is estimated at a time. This leads to the following coefficient(s) β_1 and β_2 in the previous transition probabilities (3) being denoted by:

Coefficients – b_{11} for the constant and $\boldsymbol{b_{12}}$ for the weakly exogenous variable – at Regime ***1***.

Coefficients – b_{21} for the constant and $\boldsymbol{b_{22}}$ for the weakly exogenous variable – at Regime ***2***.

The nested case of constant transition probabilities considers $\boldsymbol{b_{12}} = 0$ and $\boldsymbol{b_{22}} = 0$.

To assess the impact of a significant coefficient of a fundamental variable (i.e., considered a friction level), a first order Taylor approximation for the transition probability is made for a small value around our weakly exogenous variable x_{t-1} valued at the mean ($\bar{x}$).

For example being in regime 1 at $t-1$, i.e. $\Delta_{t-1}= 1$, and remaining in regime 1 for the next period, i.e. $\Delta_t= 1$; and for a small value of x_{t-1} around the mean $\bar{x}$:

$P(\Delta_t= 1 \mid \Delta_{t-1}= 1 , x_{t-1}; \beta_0) =$

$$= \quad P(\Delta_t = 1 \mid \Delta_{t-1} = 1 , x_{t-1}; \beta_0)|_{x_{t-1} = \bar{x}} + \frac{\partial P(\%)}{\partial x} |_{x_{t-1} = \bar{x}} * (x_{t-1} - \bar{x})$$

$$= \quad P(\Delta_t = 1 \mid \Delta_{t-1} = 1, \bar{x} \,; \beta_0) \; + \; \boldsymbol{b}_{12} \frac{\exp(x'_{t-1}\beta_0)}{[1+\exp(x'_{t-1}\beta_0)]^2} |_{x_{t-1} = \bar{x}} * (x_{t-1} - \bar{x})$$

results in:

$$P(\Delta_t = 1|\Delta_{t-1} = 1, x_{t-1}; \beta_0) - P(\Delta_t = 1|\Delta_{t-1} = 1, \bar{x} \,; \beta_0) = \boldsymbol{b}_{12} \frac{\exp(\mathrm{b}_{\mathbf{11}}+\mathrm{b}_{\mathbf{12}}*\bar{\mathrm{x}})}{[1+\exp(\mathrm{b}_{\mathbf{11}}+\mathrm{b}_{\mathbf{12}}*\bar{\mathrm{x}})]^2} *(x_{t-1} - \bar{x})$$

Or

(4) $$\Delta\, P(\Delta_t = 1 \mid \Delta_{t-1} = 1 , \boldsymbol{x_{t-1}} - \boldsymbol{\bar{x}}; \beta_0) = \; \boldsymbol{b}_{12} \frac{\exp(\mathrm{b}_{\mathbf{11}}+\mathrm{b}_{\mathbf{12}}*\bar{\mathrm{x}})}{[1+\exp(\mathrm{b}_{\mathbf{11}}+\mathrm{b}_{\mathbf{12}}*\bar{\mathrm{x}})]^2} *(x_{t-1} - \bar{x})$$

That is, a small change (e.g. an increase in the probability of remaining in regime 1 - spillover effect) resulting from a small change in the weakly exogenous variable $\boldsymbol{x_{t-1}}$ around the mean $\bar{x}$**,** is equal to the product of three terms. These terms are - the coefficient ($\boldsymbol{b_{12}}$) of the weakly exogenous variable, the logarithmic expression of the constant coefficient ($\boldsymbol{b_{11}}$) and the product of the variable's coefficient **(**$\boldsymbol{b_{12}}$**)** with the mean of the variable ($\bar{x}$), and the small change of this variable around the mean ($\boldsymbol{x_{t-1}} - \boldsymbol{\bar{x}}$). There are three basic cases which may occur regarding a small change in the weakly exogenous variable around the mean (i.e., $\boldsymbol{x_{t-1}} - \boldsymbol{\bar{x}}$**).**

If the coefficient $\boldsymbol{b_{12}}$ of our weakly exogenous variable is insignificant, then this underlying fundamental variable does not form a friction level for correlations between the markets due to price variations. Thus changes in this fundamental variable do not make an impact in the evolution of the correlations, and these market correlations evolve unaffected by changes in this particular fundamental factor.

A different situation takes place if this coefficient $\boldsymbol{b_{12}}$ is significant and positive, from where two cases emerge according to (4). One case occurs when the product of $\boldsymbol{b_{12}}$ with the logarithmic expression of the constant coefficient $\boldsymbol{b_{11}}$ and the product of the variable's coefficient **(**$\boldsymbol{b_{12}}$**)** with the mean of the variable ($\bar{x}$), is large. Then positive variations of our weakly exogenous variable with respect to the mean $(\boldsymbol{x_{t-1}} - \boldsymbol{\bar{x}})$ will lead to a higher probability of remaining at regime 1 (i.e., a longer spillover effect). The other case considers this former product being zero or very small, resulting in no further spillover effect from positive (or negative) variations of our related variable with respect to the mean.

In other words for this second case – the coefficient $\boldsymbol{b_{12}}$ being positive and significant – determines an existing friction level from this related variable. Yet the effect of increases in this weakly exogenous variable around its mean are dampened because the terms multiplied by this variable, specifically the product of $\boldsymbol{b_{12}}$ and the logarithmic expressions of $\boldsymbol{b_{11}}$ and the product of the variable's coefficient $\boldsymbol{(b_{12})}$ with the mean of the variable $(\bar{x})$, are very small or negligible. Thus the friction level identified may produce spillover effects. However no additional spillover effects would be obtained from increases, shocks, in the related variable with respect to its mean.

Conversely, it may be that the coefficient $\boldsymbol{b_{12}}$ is significant and negative at (4), and its product with the logarithmic expression of the constant coefficient $\boldsymbol{b_{11}}$ and the product of the variable's coefficient $\boldsymbol{(b_{12})}$ with the mean of the variable $(\bar{x})$, is large. Then positive variations of our weakly exogenous variable $(\boldsymbol{x_{t-1}})$ around its mean $(\bar{x})$ will lead to a lower probability of remaining at regime 1 or a higher probability of switching to a different regime – in this case switching to regime 2, in contrast to the possible case of the product of the two former factors being negative, yet negligible. Thus for the former, positive shocks from our fundamental variable will increase the probability of regime switching, resulting in a different correlation at the new regime, versus positive shocks from the fundamental variable having no effect.

The previous description may be summarized as follows - If $\boldsymbol{b_{12}}$ is *insignificant*, then there is *no friction* or spillover effect formed by the related variable. However, if $\boldsymbol{b_{12}}$ is *significant* there is an existing friction level and equation (4) determines its effect. To gauge the impact of the fundamental variable in the case of $\boldsymbol{b_{12}}$ being *significant* (i.e., existing friction) and for a small change in $\boldsymbol{x_{t-1}}$ about its mean ($\bar{x}$), if $\boldsymbol{b}_{12} * \frac{\exp(b_{11}+b_{12}*\bar{x})}{[1+\exp(b_{11}+b_{12}*\bar{x})]^2}$ is small, then there is a small response to shocks from the related variable $\boldsymbol{x_{t-1}}$ about its mean ($\bar{x}$). Yet, if $\boldsymbol{b}_{12} * \frac{\exp(b_{11}+b_{12}*\bar{x})}{[1+\exp(b_{11}+b_{12}*\bar{x})]^2}$ is large, then there is a larger response to shocks from the related variable with respect to its mean ($\boldsymbol{x_{t-1}} - \bar{x}$), in the form of increasing probabilities of switching or of spillover and remaining in a certain correlation regime.

This analysis also applies for the case of being in regime 2 during period *t-1* and subsequently remaining in regime 2 for next period *t* or switching to regime 1. In this case, the coefficient $\boldsymbol{b_{22}}$ corresponds to the relevant fundamental variable, and the analysis is analogous the one above.

Results:

Correlations among the markets for the different cases in each time scenario described at the end of the Data section are presented. During each different time scenario estimated, model selection may be assessed using either the Likelihood Ratio Test(LR),[11] which applies for comparing the nested model with each of the state dependent models, or by using the Rivers-Vuong[12] test criteria. The Rivers-Vuong test serves to compare between the two state dependent transition probabilities, since they are non-nested models. Estimation results are presented in tables 3, 4 and 5 for the three different scenarios or time periods with the unrestricted general model. These results are corroborated by results estimated with the restricted model.

[11] LR (λ) = 2*($\mathcal{L}_{ur} - \mathcal{L}_r$) ~ X_q^2 , with *q*: number of constraints.

[12] Rivers-Vuong test from Rivers-Vuong (1991) and (2002): $V_{12} = \{L_1 - L_2\}/\sqrt{\hat{S}T}$, with L_1 & L_2 maximum likelihood of each model, T: # periods considered, $\hat{S}$: Newey-West estimate for the variance of the time series of likelihoods differences. $V_{12} \sim N(0,1)$ with positive values favoring model 1 and negative values favor model 2. Denoting the sum of sectoral likelihoods for model i (i = 1,2) at time t by $L_{i,t}$, and $d_t = L_{1,t} - L_{2,t}$, then:
$\hat{S}(T, q) = \gamma_0 + 2\sum_{j=1}^{q}[1 - \frac{j}{q+1}]\gamma_j$, where γ_j denotes the sample autocorrelation of order *j* of the d_t time series.

Table 3 presents the results during the full time period scenario - from September 1998 to August 2008 - for the three cases of transition probabilities, (i) constant transition probabilities, (ii) state dependent transition probabilities considering the ratio of soybeans to corn futures harvest prices as a fundamental variable, and (iii) state dependent transition probabilities considering the 'use to stock' ratio for corn as a fundamental variable.

Applying the LR test between the case of constant transition probability (i.e. nested model) versus the two state dependent probability models results in a clear preference of the state dependent probability cases. This is inferred since the LR (λ) statistic is clearly above the critical value for the X_2^2 of 13.82, for significance at the 1% or lower. Applying the Rivers-Vuong test for the two latter cases results in a minor, but insignificant, preference of the model considering corn's 'use to stock' ratio as weakly exogenous variable, since the RV_{12} statistic is less than 0.5.

The two state dependent probability cases have very similar estimated correlations. The dynamic correlations between corn and soybeans are significant at both regime levels with values of 0.758 and 0.338, respectively. These are both positive values as anticipated, since these crops share common production conditions. Likewise, positive and significant values of 0.8188 and 0.2492 are determined, respectively, for the correlations between feeder cattle and live cattle (fed cattle) at both regimes as expected again by the literature, since these two markets are directly related in the marketing chain.

A negative significant correlation value of -0.275 is determined between corn and feeder cattle prices at the high correlation level. This may be anticipated by the literature (Anderson and Trapp, 2000), responding to an increase in the price of corn previously noted in figure 1.1, since corn is a main component of the feed ration. This inverse significant result is also obtained for the soybean and feeder cattle prices at -0.229. Soybeans are also an important source of protein feed, and this crop had a similar increase in its price evolution noted in figure 1.2, being positively correlated to corn during all time periods.

Another finding is that there is no significant correlation between corn prices and live cattle prices at either regime level. This reveals a level of permanent adjustment cost, as higher feed prices are not passed on to the live cattle prices. This may be a direct consequence of modifying feed rations when faced by increased corn prices, also anticipated by Anderson and Trapp (2000). This adjustment or transaction cost may be formed by information and/or negotiation costs faced by cattle producers when selling their fed cattle in the market. Information costs may rise by price uncertainty during the selling period from using auction channels, and negotiation costs may come from sellers of fed cattle having comparable lower market power over the buyers (Hobbs, 1997). More analysis follows in the discussion section.

In addition, a positive correlation between soybean prices and live cattle prices at the lower correlation regime is found. It is not clear at this point what this may respond to and may be a spurious result. The dynamic correlations between corn and soybeans for state dependent transition probabilities considering the weakly exogenous variable 'use to stock' ratio, and for the constant transition probabilities, are in figures 8.1 and 8.2.

In table 4 the estimated results for the second scenario are presented; i.e., from September 1998 to August 2004 (the period before the ethanol driven corn consumption). Applying the LR test, the two state dependent probability models are preferred to the constant transition probability model at the 5% level or less. However, upon comparing the two state dependent models by the Rivers-Vuong criteria, it is determined that there is a not a significant preference of the model with the corn 'use to stock' ratio over the soybeans to corn price ratio, since the RV_{12} statistic is less than 0.3

For both these latter models, correlations between corn and soybean prices at both regimes are at odds. Positive values of 0.681 and 0.388 are for the model considering 'use to stock' ratio at regimes 1 and 2, respectively. Yet positive values of 0.4144 and 0.6282 are for the soybean to corn price ratio model at regimes 1 and 2, respectively. However, the difference of these latter values appears small in magnitude when compared to the magnitude of their standard errors.

Regarding the correlation values between feeder and fed cattle markets - both models have similar positive values at regimes 1 and 2 respectively, at 0.844 or 0.8458 and 0.276 or 0.3099. Moreover, these values from both regimes are similar to the previous time period scenarios. A difference with respect to the previous estimated scenario is that in this time period there is no statistical negative relationship between corn and feeder calf prices. This is an interesting point that may be anticipated, as there was not a substantial increase in corn prices during this pre ethanol driven corn consumption period. Thus corn prices had no effect on feeder cattle prices. Here the state dependent transition probabilities for corn's 'use to stock' ratio are insignificant and do not have an effect on the dynamics of the correlations among the markets.

Table 5 below is for the last scenario (i.e. from September 2003 to August 2008), which specifically considers the effect of the ethanol driven corn consumption. Application of the LR test results in the two state dependent transition probability models being chosen over the constant transition probability model, since the λ statistic determined is over 25 and 35, respectively. And of these two latter models, the model that uses the corn 'use to stock' ratio as a weakly exogenous variable is mildly preferred by considering the Rivers-Vuong criteria which resulted in a RV_{12} of 1.54 ($p < 0.15$).

Similar positive correlations for corn and soybeans at 0.874 and 0.304 are obtained at both regimes. However, the high regime correlation value is slightly larger, considering the standard errors, than for the pre-ethanol corn consumption period described before. Thus the high correlation regime may have increased correlations as a result of the increased demand for corn consumption. The feeder and live cattle prices also had positive correlations of 0.804 and 0.326 at the two regimes, of similar range in comparison to the previous scenario. This scenario has an inverse correlation for both corn and feeder prices and for soybean and feeder prices, at the high regime of -0.378 and -0.369, respectively. This result has similar values, though slightly higher, than the first scenario. The result corroborates that increases in corn price – substantially present during this scenario (figure 1.1), lead to a higher correlation with soybean price and both of these affect substantially the feeding composition of cattle production. It is plausible that this increased corn price is caused from the ethanol driven corn consumption, as mentioned before.

Similar to the previous two scenarios, there is no correlation between corn and live cattle markets. Since corn is regarded as the main feeding component for livestock, this finding reveals a permanent transaction or adjustment cost materialized through the modification of the feeding rations given to the livestock.

Likewise there is a positive correlation between soybean and live cattle at the second or lower correlation regime (i.e., corn and soybean have a lower correlation). It is not apparent why these two series would have such a relationship, possibly being a spurious result and/or requiring further analysis to determine its plausible causes.

Discussion

Dynamic correlations where determined for two different regimes between prices of corn, soybean, feeder- cattle and fed- or live- cattle under three distinct time periods or scenarios. These estimated correlations corroborate earlier findings with respect to the sign of their values; i.e., positive correlations between corn and soybean prices since these crops share planting acreage and likewise positive correlations for feeder and fed cattle, since they are main components in the cattle production industry. In addition, a negative correlation was determined between prices of corn and feeder cattle during the second period of increasing corn prices, also anticipated since cattle producers are forced to pay less for calf or feeder cattle replacement to maintain profitability.

An unexpected finding regarding the relationship between the market prices of corn and fed or live cattle was determined. Under the three different time scenarios, but especially during the period of increasing corn consumption from ethanol production, the correlation between corn and live cattle markets was always negligible or non-existent. In other words, even for the scenario of higher feed costs due to rising corn prices, the relationship between corn and live cattle prices remained insignificant. This reveals a permanent transaction or adjustment cost that may have been materialized by modifying the feed rations for livestock, during the last period of increased corn demand. This permanent adjustment may respond to transaction costs faced by cattle producers when selling fed cattle for slaughter in the market. These transaction costs may be from information and/or negotiation costs (Hobbs, 1997) resulting in no transmission of price variations between these two markets (i.e. their dynamic prices behave as unrelated).

Information costs may result from price uncertainty for fed cattle being sold as slaughter cattle, through cash or spot markets. These cash markets refer to transactions being ‘on the spot’ (RTI 2007), and include auction barn sales, video or electronic auction sales, sales through order from buyers, dealers and brokers and also direct trades. In this sense, cattle producers may need to change feed rations from components with increasing costs, such as corn, in order to keep costs down during production as they face uncertainty in the selling price of their product, assuming they have previously not hedged this price. The negotiation costs faced by cattle producers may respond to a limited number of different auction channels available when the cattle is ready to be slaughtered, thus raising the transaction cost involved in using that selling arrangement.

Producers selling directly with pre-established 'alternative marketing arrangements' (AMA) to packers - which includes forward contracts, marketing agreements, procurement or marketing contracts, production agreements, packer ownership, custom feeding and slaughter - accounted for less than 40 percent of all fed cattle volume sales from October 2002 to March 2005, per RTI (2007). In this case, negotiation costs may arise due to having only a few packers to bargain with, resulting in the packer exercising marketing power on the cattle producer. Once again, this may lead the cattle producer to seek modifying the feed rations when there is a price increase in some of the feed components, as is the case of corn during the third time period scenario considered. But even more important for the other time period scenarios, these transactions costs reveal the conditions which cattle production faces with respect to sales of slaughter cattle.

A main result from the scenario of *post ethanol corn consumption* is the finding of two significant positive coefficients for the state dependent model that incorporates the corn 'use to stock' ratio as the fundamental variable (our statistically preferred model).[13] These coefficients - b_{12} and b_{22} are included in the probability of being in regime 1 and either staying there or switching to regime 2 (i.e., coefficient b_{12}) and for the probability of being in regime 2 and either staying there or switching to regime 1 (i.e., coefficient b_{22}), respectively.

As the corn 'use to stock' ratio changes from its mean, the probability of being at regime 1 and remaining there or switching to regime 2 or, conversely, being at regime 2 and remaining

[13] An economic analysis considering the effects of the 'ratio of soybeans to corn prices' as the weakly exogenous variable may provide plausible results, especially considering the significant coefficients obtained in the estimation of the last time period scenario. However, given the mild preference (at 15% level or less) provided by the Vuong test for the model with the 'use to stock' ratio of corn, the analysis focused more on the effects of this latter variable.

there or switching to regime 1 depends on the product of three terms from equation (4). One term is the logarithmic function of the sum of the coefficient of the constant variable (i.e. b_{11} for regime 1 or b_{21} for regime 2) and the product of the coefficient of the variable (i.e. b_{12} for regime 1 or b_{22} for regime 2) times the average of the use to stock ratio. The other term is the coefficient of the variable itself (i.e. b_{12} or b_{22}), and the third term is the change of the corn's use to stock ratio with respect to the mean. The values obtained for the product of these factors, as well as the impact of shocks from the weakly exogenous variable - corn 'use to stock' ratio - on the probability of remaining at a certain regime level of correlation are computed according to equation (4), and shown in table 6.

For this scenario of post mandated ethanol corn consumption, there is a small effect in the probability of remaining in the higher correlations at regime 1 for an increase in the corn 'use to stock' ratio, and thus producing a spillover effect. In other words, during the period from 2004 to 2008, a 5% or 15% increase in corn's 'use to stock' ratio would produce an increase in the probability of remaining in regime 1 of about 0.036 or 0.107, respectively. This is a small rise in spillover effect driven by shocks to the 'use to stock' corn ratio. Conversely, if the ratio decreased in the same amount, i.e. by either 5% or 15%, then the probability of remaining at regime 1 would lower by 0.036 and 0.107, respectively. This latter is equivalent to a similar increase in the probability of switching to regime 2, from previously being in regime 1.

More importantly, we identify that shocks to the 'use to stocks' ratio of corn would increase or decrease much further the spillover effect present in regime 2. From table 6, a 5% or 15% increase in corn's 'use to stock' ratio would produce an increase in the probability of remaining in regime 2 of about 0.109 or 0.327. This larger effect of corn's use to stock ratio in the probability of staying at regime 2, in comparison to constant transition probability, may be observed from the positive correlations between soybeans and corn during this post ethanol corn consumption period in figures 9.1 and 9.2, respectively.

As may be noted, there is an evident spillover effect identified at the lower correlation regime (i.e., regime 2), when considering the inclusion of the 'use to stock' ratio of corn, in comparison to the regular constant transition probability model. The spillover effects identified at this low correlation regime occur when there is a steady rise in corn consumption, in comparison to the available stock. That is, both persistent or spillover effects occurring at the low correlation levels happen during a continual increase in corn's 'use to stock' ratio to values considerably higher than the usual values that had been prevalent before 2003, as may be noted from figure 7.1. The first persistent low correlation period occurred from early January 2004 till August of that year, a period of unusual low stock before additional corn production came into the market at the end of the year, to satisfy the demand.

The more noticeable spillover effect occurred from December 2006 till late June 2007, when the ethanol corn consumption had an enormous increase of about 25%, from 1600 million bu. to more than 2,100 million bu. as can be seen from figure 4. This demand increase was being satisfied with previous higher production levels from year 2006. However, it was not enough to keep the stock levels unaffected, resulting in a substantial stock decrease. After the harvest period of year 2007 and record corn production, these stocks rose considerably and dropped the corn 'use to stock' ratio to regular levels. A rise and record production of corn was achieved in part due to acreage taken from soybean (figure 5), but also due to common corn production response to bio-tech industry new varieties and to improved agronomic production practices.

The steady increase in corn consumption during these two above mentioned periods – especially the second one, affected directly the stock of available corn. Moreover, this boost in corn demand did not affect immediately the market for soybeans, since the drop in soybean production or harvest for that period had yet to be taken into account. Thus the prices for these two crops remained at a low correlation level until the 2007 mid-year estimation report from the World Agricultural Supply and Demand Estimates (WASDE).[14] The report on soybean production confirmed an extensive amount of acreage had changed from soybean to corn production during that year. Following the mentioned report, the estimated correlation value between prices of both crops increased to the higher regime. Likewise, during the first part of this second estimated period, the prices of both crops – corn and soybeans– were in steady increase responding to the rise in demand and the lower supply, respectively.

Subsequently, during the harvest period beginning at the third quarter of 2007, corn had a record yield leading the corn ‘use to stock’ ratio to have a rapid drop from its prior sharp increase. However, for future periods the ratio still remained at levels above the pre ethanol corn consumption periods, as can be seen from figure 7.1. The spike in the ratio observed during September 2002 comes from the estimated lowest yield of corn since the mid-nineties, which reduced the estimated stocks sharply. However, the ‘use to stock’ ratio declined as consumption also declined for the year 2003 (ERS-UDSA).

The effect of the significant fundamental variable – ‘use to stock’ ratio of corn, in the state dependent transition probabilities that determine the switch between one regime of correlations and the other is shown in figures 10.1 and 10.2. These figures serve to gauge the ratio’s impact on the chance of persistence at a certain correlation regime. The first figure shows the conditional probability of remaining at the lower correlation regime 2, for the case of previously being in that regime. As it may be noted during the two previous mentioned periods (i.e., 2002 & 2006) of spillover effects at the low correlation regime, the probability of remaining at that

[14] Obtained from the USDA.

regime 2 is very close to being 1. This is in contrast to the case of only considering constant transition probabilities between regimes, where the probability of remaining at that regime 2 is only around 0.61. That is, the explicit inclusion of the significant fundamental factor – the 'use to stock' ratio of corn - in the state dependent transition probabilities between regimes, permits the identification of periods of spillover effects at the low correlation level.

In other words, by incorporating this underlying economic variable in the regime switching process of the dynamic correlations between corn and soybeans, we identify the significant spill-over impact it may have in a particular period. The 'use to stock' ratio of corn incorporates the markets' dynamic demand and supply forces for corn, including the period of higher corn consumption due to ethanol production. In particular, during this post ethanol corn consumption period, the dynamic correlations between corn and soybean, and other markets previously mentioned, reveal spillover effects that were not captured when this underlying economic variable was not considered in the dynamic regime switching process.

These identified spillover effects may be taken into account for policy analysis or efficiency gains in operations of these markets, though more analysis may be made with additional economic variables such as soybeans' 'use to stock' ratio, exchange rates, loan rates, or speculative variables such as contract volumes or others.

Conclusions

The effects of the recent increase in corn and soybean prices, and their volatilities, on cattle markets are studied by using a newly developed extension of a multivariate time series model. We specifically determine the dynamic correlations between corn, soybeans, feeder cattle and live cattle markets with an extended regime switching dynamic correlations model. The model extension enables the insertion of underlying economic variables that have an impact in the evolution of the dynamic correlations among the markets. We study the potential effect of recent policies regarding ethanol mandated production, on corn prices and its consumption.

Two partitioned scenarios or time periods are considered, where one of them is previous to the mandated ethanol production surge, and the other period is after this policy was installed. In addition, parameter estimation is first considered for the scenario depicting both previous time periods together (i.e. the initial complete time series).

Results obtained for correlations between markets such as corn and soybeans, and feeder cattle and live cattle, are positive and consistent with the literature for all three time periods considered. Likewise, a significant negative correlation between corn prices and feeder cattle for the last period considered is determined. i.e. during the post ethanol corn consumption period. However, this negative correlation is not determined for the period prior to the mandated ethanol production. This significant inverse relationship during the post ethanol period is consistent with the literature where increases in corn prices result in declining calf/feeder prices, as a response to cattle producers seeking to maintain profitability by purchasing calf/feeder at lower prices.

No transmission of prices between the corn market and the fed or live cattle markets is found. i.e., there is no correlation for prices between these two markets at any of the scenarios computed. This may respond to transaction costs in both the form of information and negotiation costs. Information costs for cattle producers may involve price uncertainty for the case of fed cattle being sold at cash or spot markets, leading producers to switch from feed rations with increasing costs, i.e. corn in the post ethanol corn consumption scenario, to feed components with lower cost. Negotiation costs may respond to the limited number of auctions faced by producers when fed cattle are ready to be slaughtered, thus raising the transaction cost for using that channel. For producers selling directly with alternative marketing arrangements to packers, negotiation costs may arise for the case of having only a few different packers to bargain with, thus resulting in the packer exercising marketing power and establishing price and conditions of delivery. This again leads the cattle producer to seek feed rations that do not experience cost increases, i.e. modifying rations when there is a price rise in some of the components as in the case of corn.

For the case of introducing underlying economic fundamental variables in the dynamic process, we find that there is a mild effect of the corn 'use to stock' ratio on the dynamic correlations among the previous markets. This ratio contains the dynamic demand and supply conditions for corn, including the increased demand for ethanol production. Specifically for the last scenario estimated, i.e. between 2004 and 2008, there is a substantial spillover effect at a low correlation regime, when compared to the previous scenarios. Thus corn and soybean experience effects of spillover - remaining at a correlation regime - when taking into account this relevant economic variable, compared to the case where this factor is unaccounted for. A plausible cause for this effect – post end of 2003, may be due to the increased corn consumption for ethanol production.

Spillover effects are unveiled when considering the related corn demand and supply variable in comparison to the case of constant probabilities between regimes. Further analysis may require additional series to be considered as weakly exogenous variables such as the soybean 'use to stock' ratio, exchange rates, and contract volumes among others.

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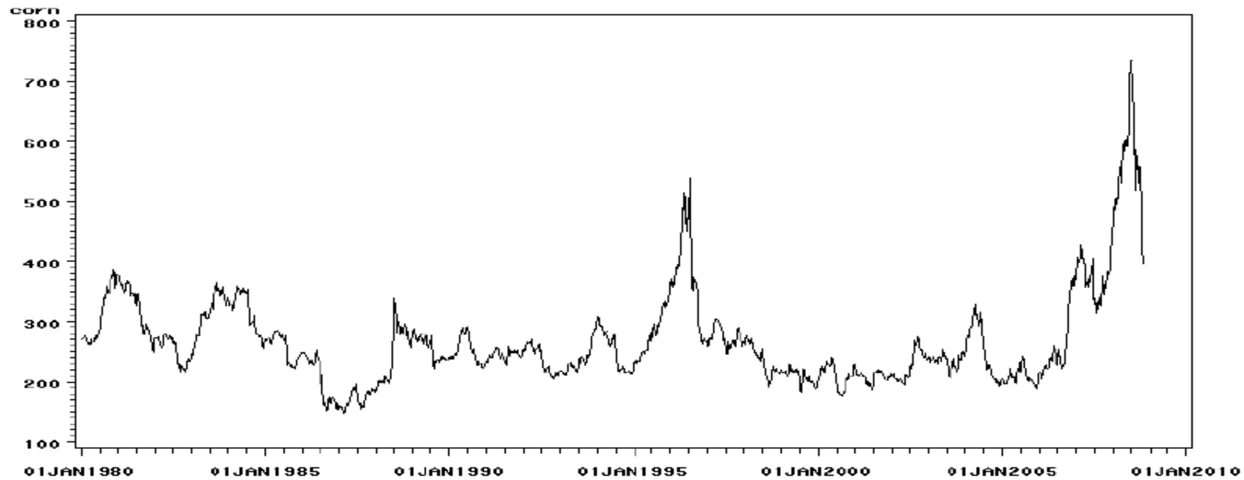


Figure 1.1: Corn Futures Prices (cents/bushel).

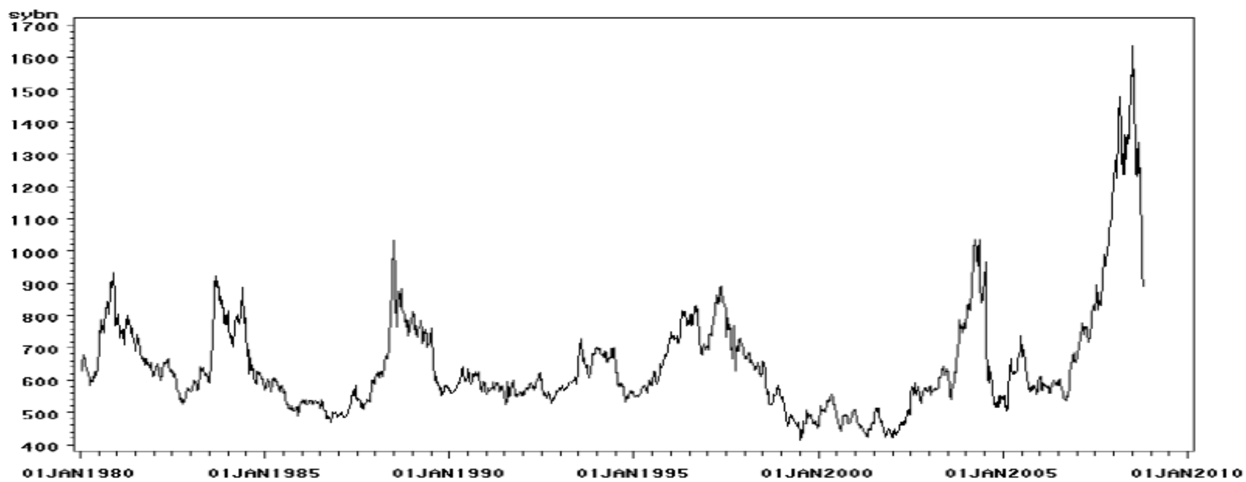


Figure 1.2: Soybeans Futures Prices (cents/bushel).

Figure 1.3: Feeder Cattle Futures Prices (cents/hundred weight - cwt).

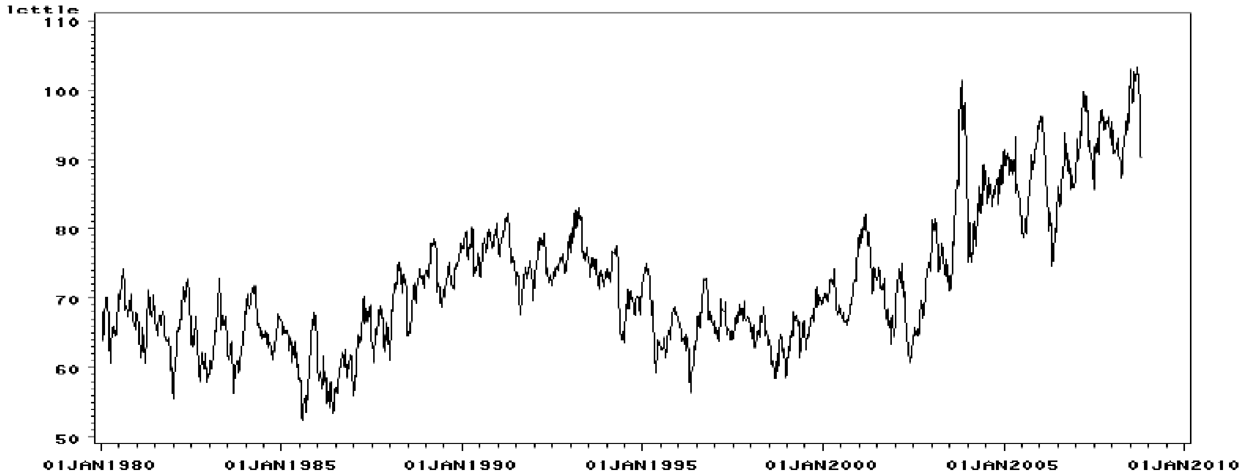


Figure 1.4: Live Cattle Futures Prices (cents/hundred weight - cwt).

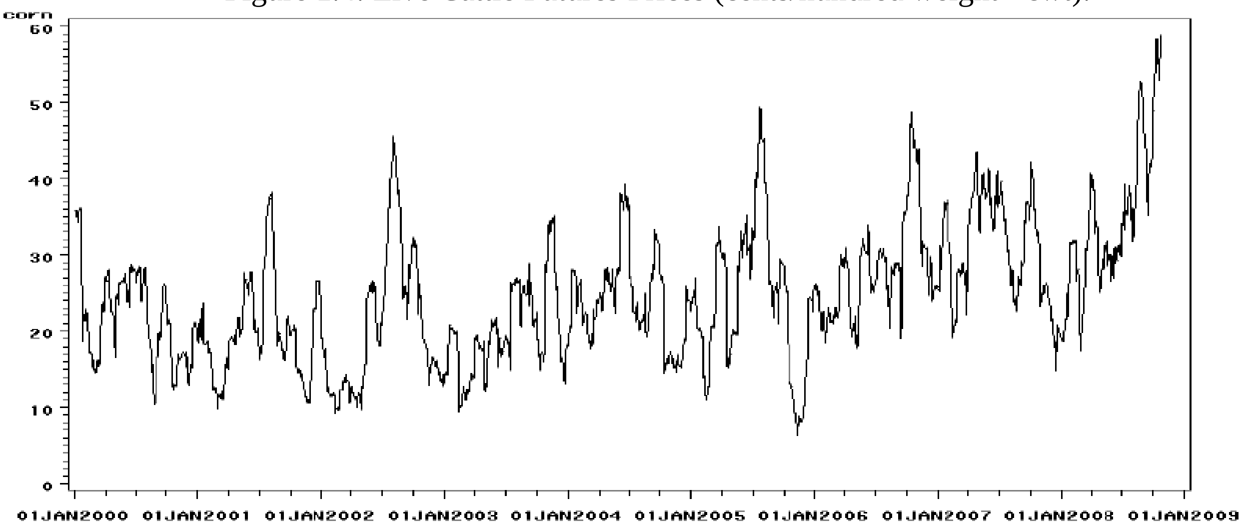
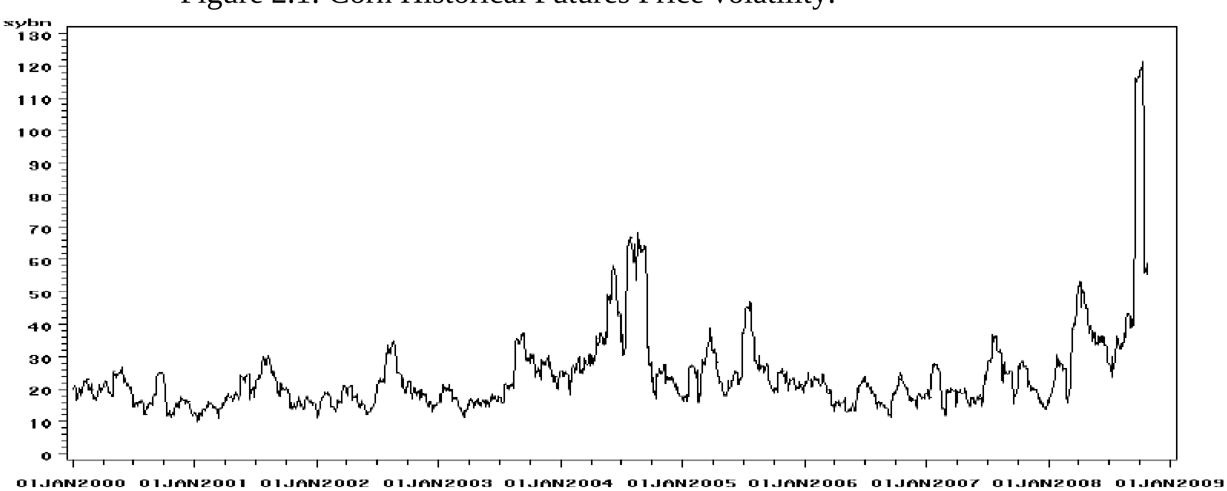


Figure 2.1: Corn Historical Futures Price volatility.



September 12 2008 - Soybean Volatility spike due to last day of trade of September contracts, with many ‘shorts’ having to deliver yet facing a smaller harvest supply due to delay in year planting. Price spiked a record of 2.74 $/bu. i.e. a case of ‘short’ squeeze.

Figure 2.2: Soybean Historical Futures Price volatility.

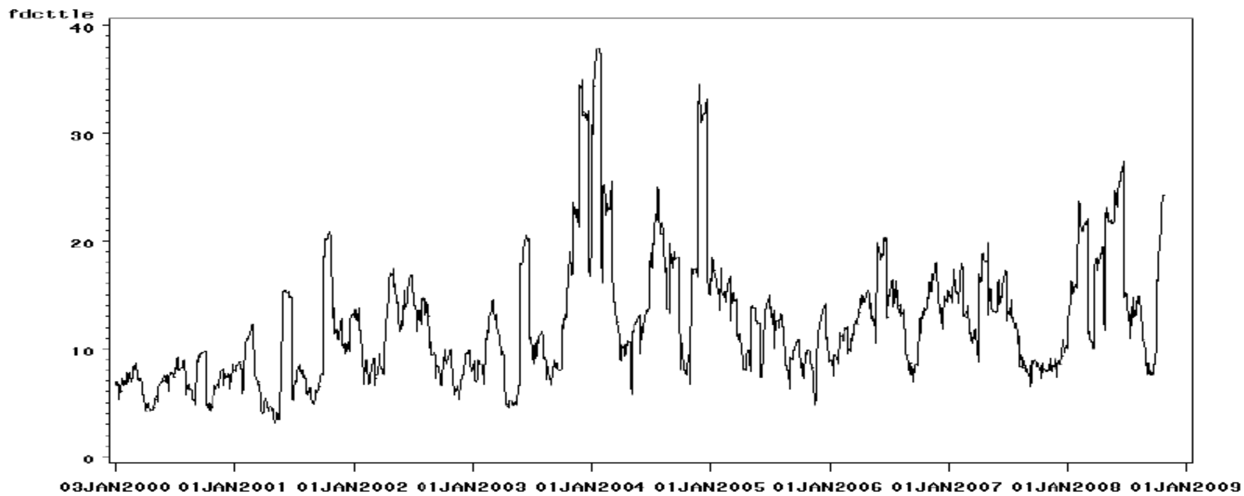


Figure 2.3: Feeder Cattle Historical Futures Price volatility.

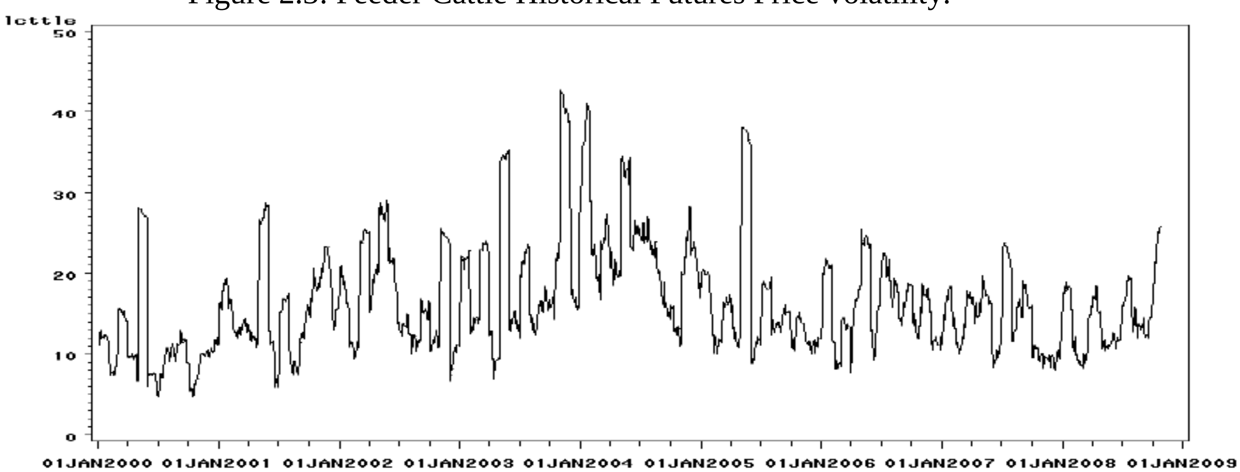


Figure 2.4: Live Cattle Historical Futures Price volatility

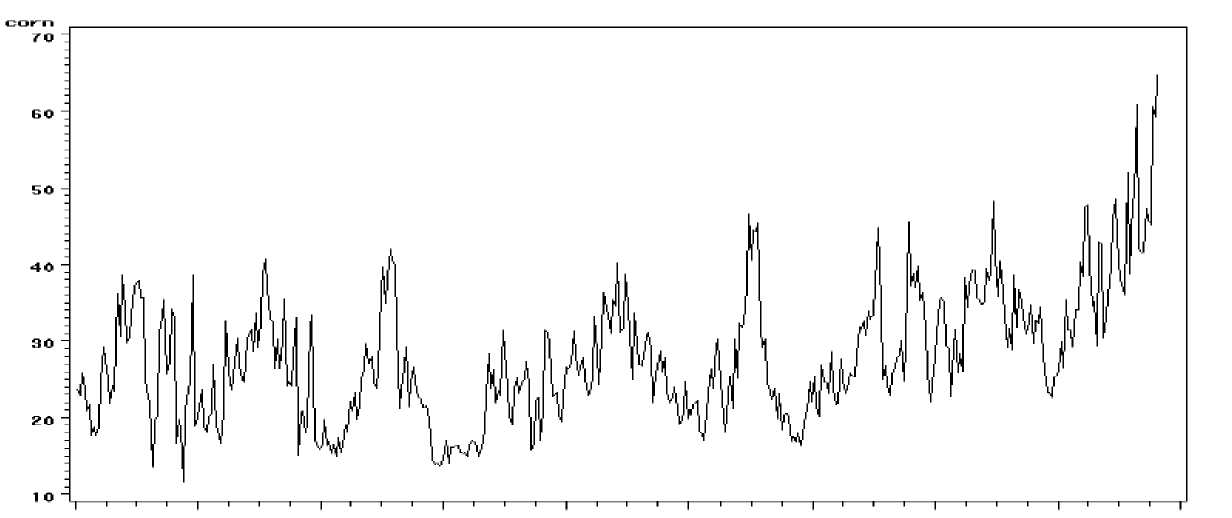


Figure 3.1: Corn Futures Prices Implied volatility.

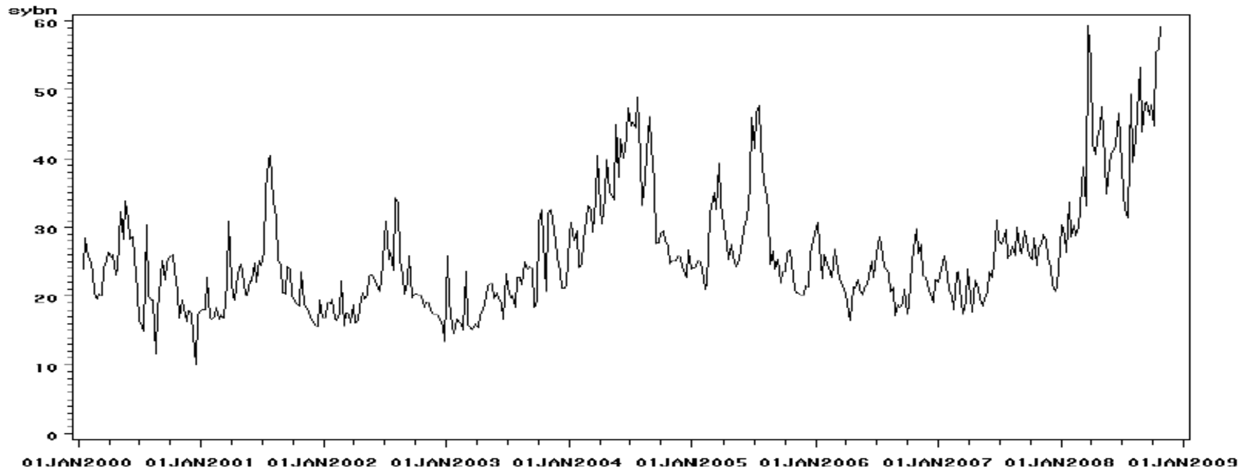


Figure 3.2: Soybean Futures Prices Implied volatility.

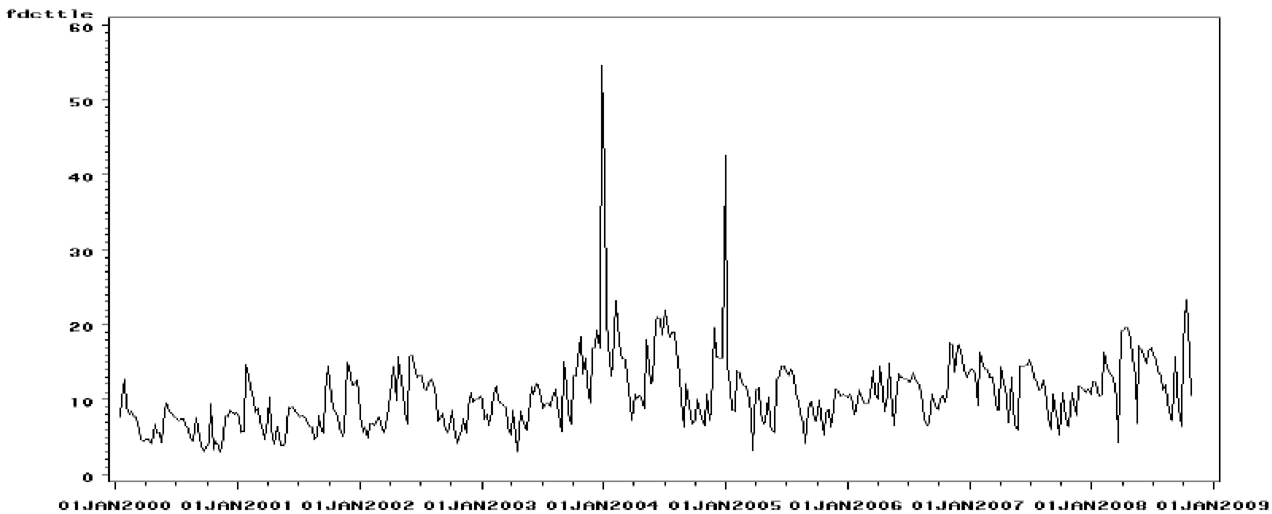


Figure 3.3: Feeder Cattle Futures Prices Implied volatility.

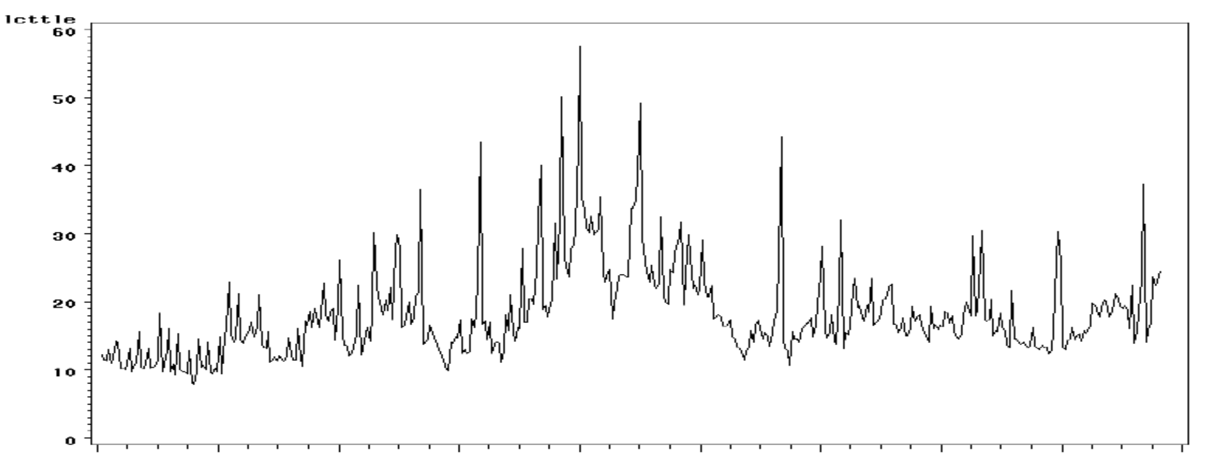
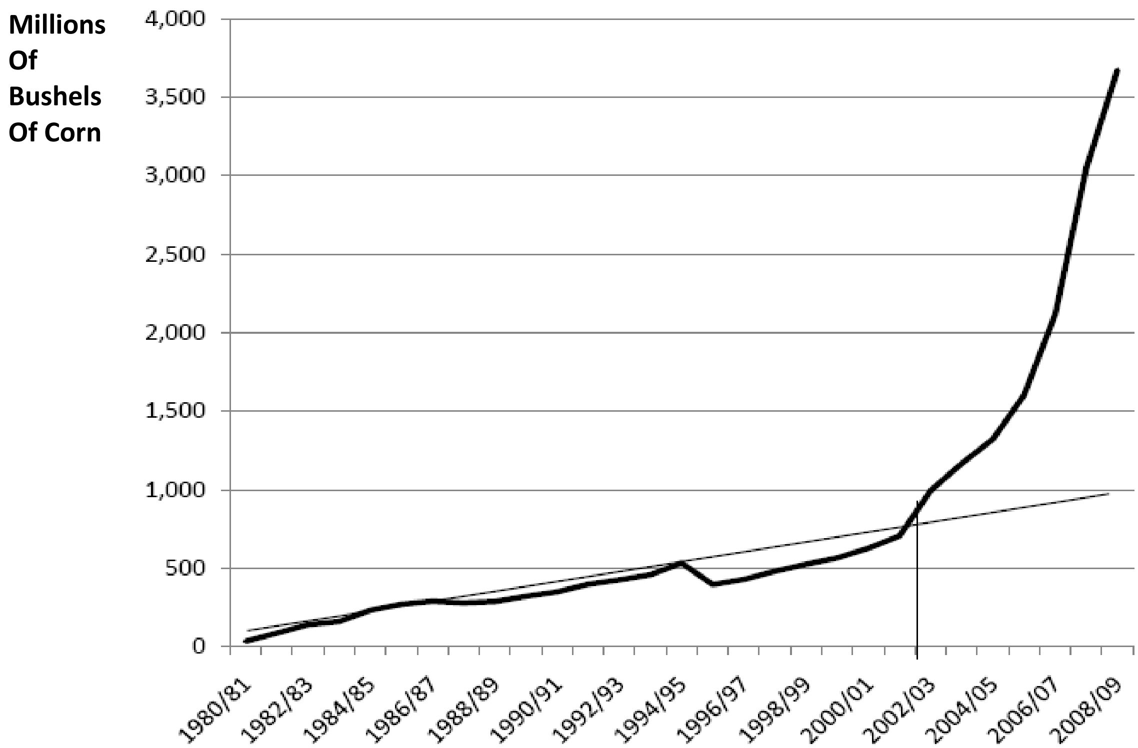
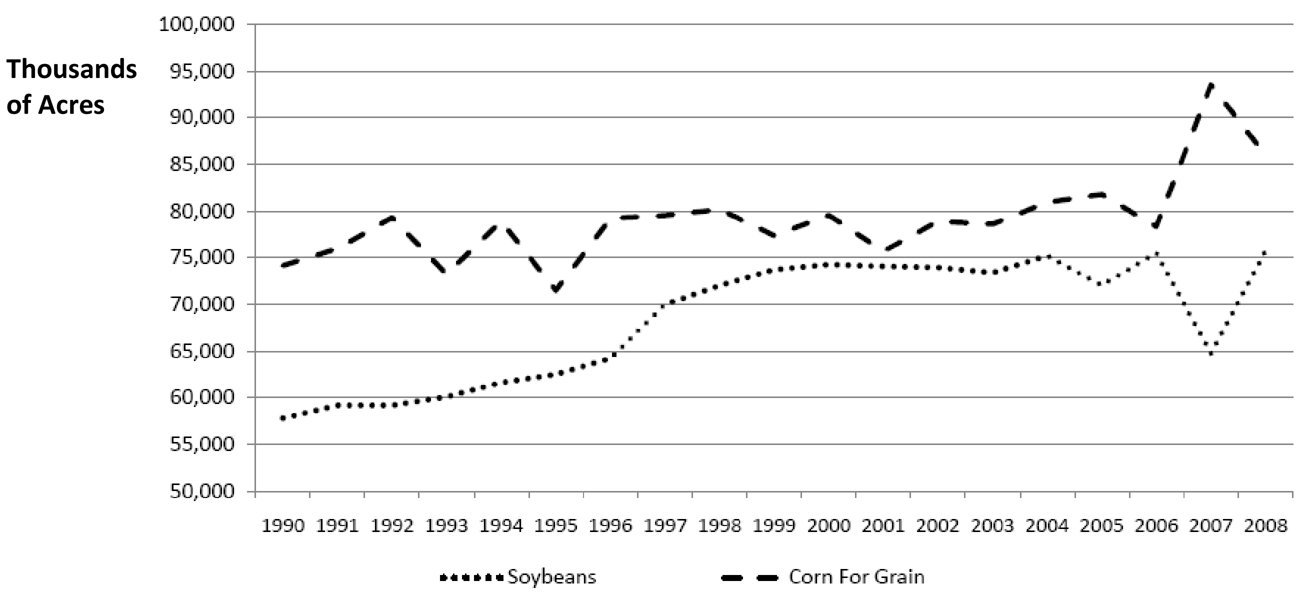


Figure 3.4: Live Cattle Futures Prices Implied volatility.



Source: Economic Research Service, USDA

Figure 4: Corn consumption from Ethanol production (in millions of bushels).



Source: NASS – USDA

Figure 5: U.S. Yearly All Purpose Planted Crops (thousands of Acres)

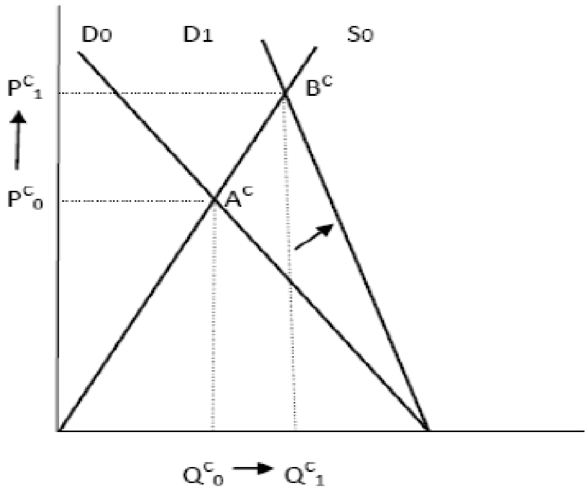


Figure 6.1: Corn Demand has an outward shift due to Ethanol corn consumption.

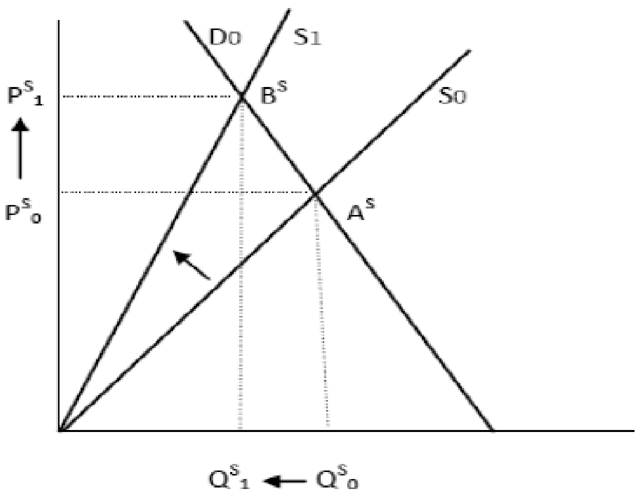


Figure 6.2: Soybean Supply has an inward shift due to acreage transferred for corn production.

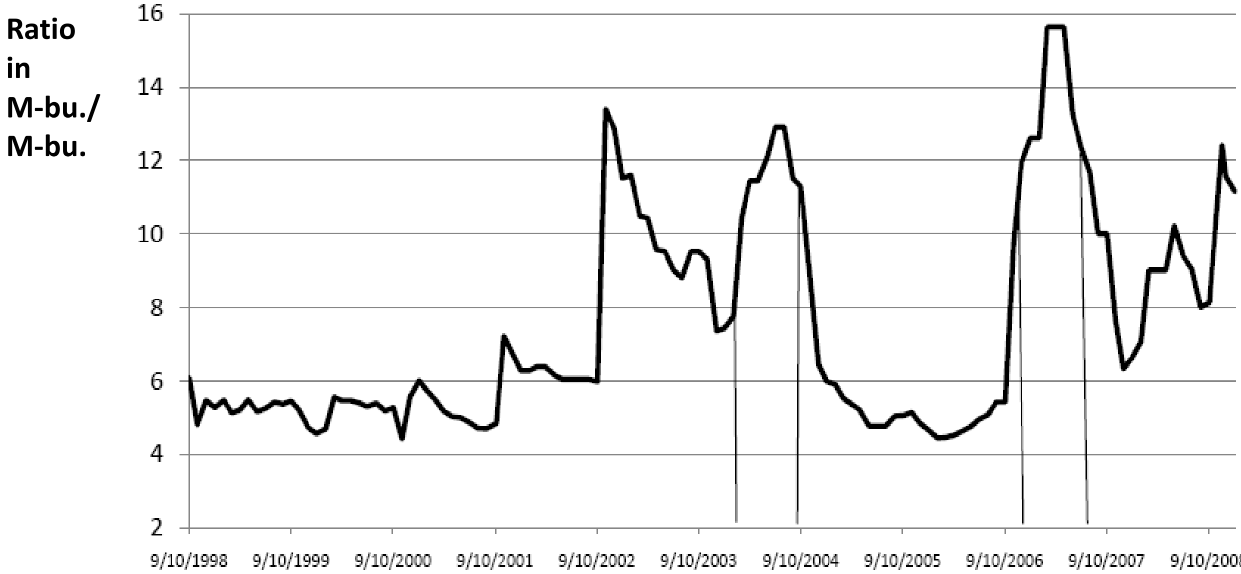
Table 1: Summary Statistics for Futures Prices – Weekly Average

	Corn[15]	Soybean	Feeder Cattle[16]	Live Cattle
September 1998 to August 2008				
Mean	264.09	649.19	94.25	79.45
Std Devtn.	102.07	242.90	14.39	11.12
Max	735.05	1634.19	119.07	102.93
Min	175.90	412.94	66.76	58.40
September 1998 to August 2004				
Mean	223.97	556.45	84.71	72.58
Std Devtn.	27.86	136.09	9.73	8.22
Max	329.19	1036.55	118.35	101.42
Min	175.90	412.94	66.76	58.40
September 2003 to August 2008				
Mean	312.00	793.49	106.75	88.98
Std Devtn.	126.21	271.21	7.80	6.01
Max	735.05	1634.19	119.07	102.93
Min	188.10	505.70	81.62	74.66

Table 2: Summary Statistics for Futures Log Returns

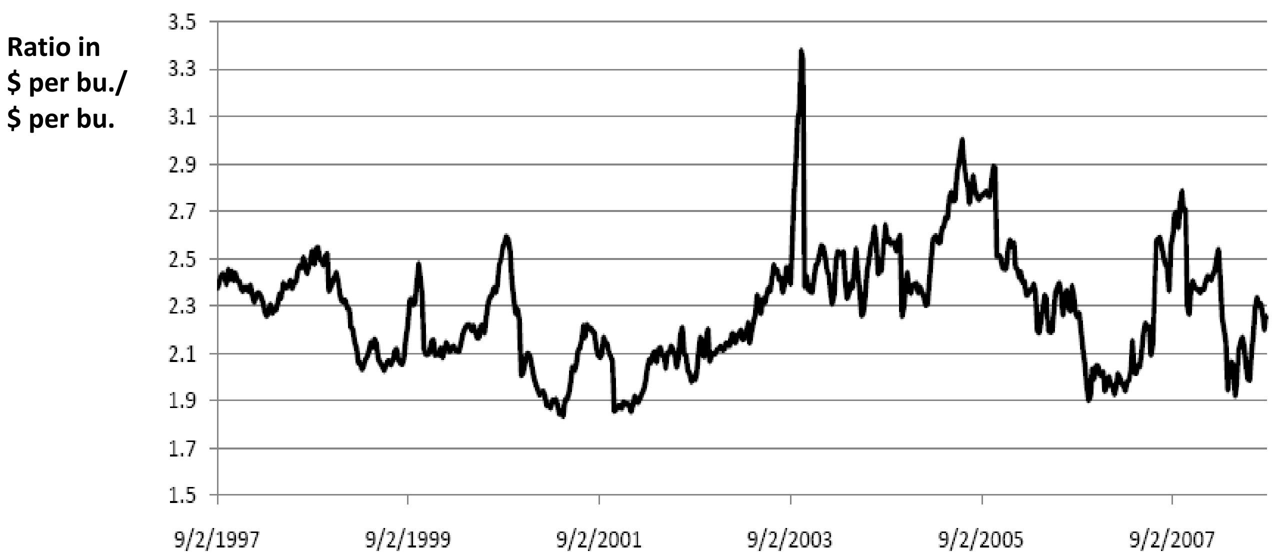
	Corn	Soybean	Feeder Cattle	Live Cattle
September 1998 to August 2008				
Mean	0.21	0.18	0.10	0.11
Std Devtn.	3.22	3.10	1.76	2.25
Max	10.37	9.61	5.58	6.31
Min	-12.59	-18.44	-13.82	-15.13
September 1998 to August 2004				
Mean	0.05	0.05	0.18	0.11
Std Devtn.	2.81	3.01	1.72	2.41
Max	10.10	8.56	5.58	6.31
Min	-11.47	-18.44	-13.82	-15.13
September 2003 to August 2008				
Mean	0.35	0.32	0.06	0.07
Std Devtn.	3.67	3.72	2.12	2.45
Max	10.37	9.61	5.55	6.31
Min	-12.59	-18.44	-13.82	-15.13

[15] Corn and Soybean Price units are in Cents per bushel (bu.). Minimum contract is for 5,000 bushels
[16] Feeder Cattle and Live Cattle Price units are in Cents per hundred weight (cwt.). Minimum contract for Feeder Cattle is for 50,000 lbs. Minimum contract for Live Cattle is for 40,000 lbs.



Source: WASDE – USDA

Figure 7.1: Corn – Use to Stock Ratio



Source: WASDE - USDA

Figure 7.2: Ratio of Soybeans Futures Prices with delivery November (X) to Corn Futures Prices with delivery in December (Z)

Table 3: Estimated Betas - Unrestricted Model between September1998 and August 2008.

UN_Restricted Model

	Constant Transition Probability (by DP)	Standard Error	*State Dependent Probability Ratio Sybn/Corn Price*	Standard Error	*State Dependent Probability Ratio USE_Stock*	Standard Error
Likelihood	*-4528.1*		*-4518.3*		*-4510.0*	
Γ1 - Correlation Regime 1.						
Corn –Soybean	*0.4274**	0.1483	*0.7261**	0.0709	*0.7584**	0.0328
Corn -Feeder Cattle	*-0.3651**	0.0758	*-0.3371**	0.0672	*-0.2750**	0.0726
Corn - Live Cattle	0.0161	0.1125	-0.0326	0.0750	-0.0292	0.0700
Soybean - Feeder Cattle	-0.0786	0.0774	*-0.2396**	0.0782	*-0.2291**	0.0717
Soybean - Live Cattle	0.1200	0.0830	-0.0283	0.0870	-0.0347	0.0753
Feeder Cattle -Live Cattle	0.8121*	0.0738	*0.8205**	0.0252	0.8189*	0.0278
Γ2 - Correlation Regime 2.						
Corn –Soybean	*0.6694**	0.0969	*0.3872**	0.0858	*0.3382**	0.0671
Corn -Feeder Cattle	0.0195	0.0749	0.0054	0.0653	-0.0356	0.0766
Corn - Live Cattle	-0.0197	0.0984	0.0148	0.0753	0.0239	0.0738
Soybean - Feeder Cattle	0.0359	0.0788	*0.1485**	0.0616	*0.1595**	0.0609
Soybean - Live Cattle	0.0005	0.0705	0.0994	0.0750	0.1126+	0.0650
Feeder Cattle -Live Cattle	*0.3038**	0.0940	*0.2708**	0.0524	*0.2492**	0.0537
γ or β - Betas						
probability beta - b11	*0.5423**	0.1523	3.0370	3.4463	-0.5244	1.1144
probability beta - b21	*0.5875**	0.2767	4.4614+	2.6006	-6.4689	4.1636
probability beta - b12	0		-1.3165	1.5669	0.0600	0.1583
probability beta - b22	0		-2.0072+	1.1820	0.6963	0.4475

* Significant at 5% level or less

\+ Significant at 10% level or less

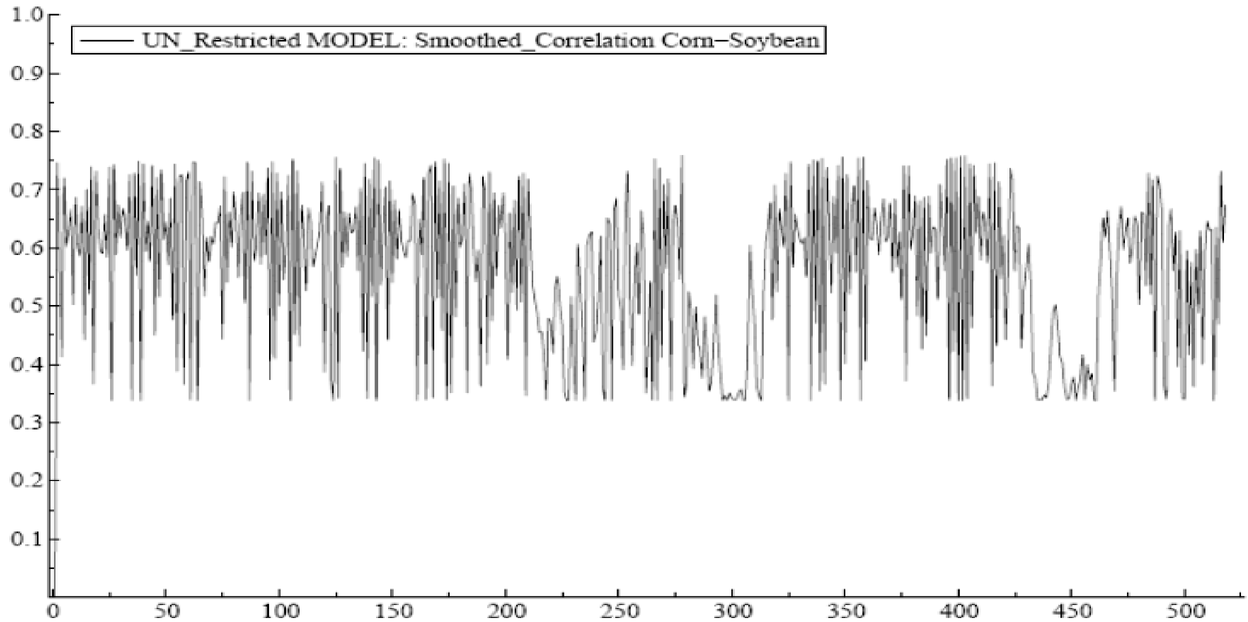


Figure 8.1: Smoothed Dynamic Correlations between Corn and Soybeans with *State Dependent transition probabilities* – considering 'use to stock' ratio. Weekly data from September 1998 to August 2008.

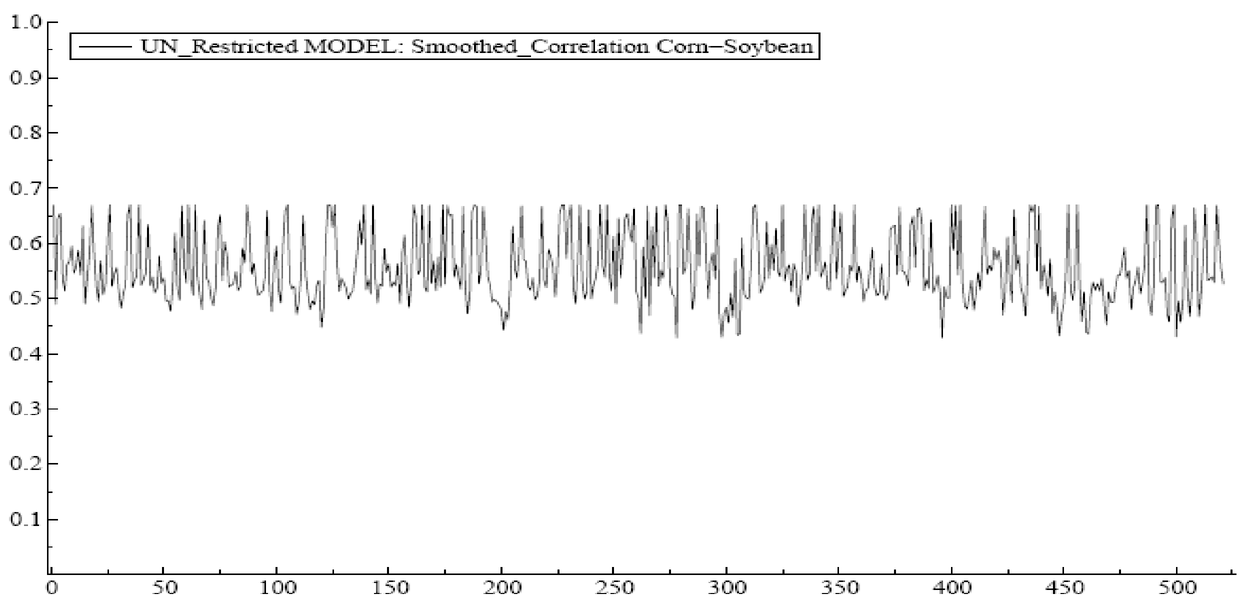


Figure 8.2: Smoothed Dynamic Correlations between Corn and Soybeans with *Constant transition probabilities*. Weekly data from September 1998 to August 2008.

Table 4: Estimated Betas - Unrestricted Model between September 1998 and August 2004

UN_Restricted Model

	Constant Transition Probability (by DP)	**Standard Error**	***State Dependent Probability Ratio Sybn/Corn Price***	**Standard Error**	***State Dependent Probability Ratio USE_Stock***	**Standard Error**
Likelihood	*-2652.0*		*-2641.4*		*-2639.2*	
Γ1 - Correlation Regime 1.						
Corn -Soybean	0.3647	0.2251	0.4144+	0.2245	*0.6811**	0.0489
Corn -Feeder Cattle	*-0.1986**	0.0766	*-0.2214**	0.0687	-0.2021	0.1544
Corn - Live Cattle	0.1445	0.1206	0.1258	0.1168	0.0419	0.0759
Soybean - Feeder Cattle	-0.0758	0.0993	-0.0690	0.1048	-0.1500	0.1868
Soybean - Live Cattle	0.1004	0.1075	0.1159	0.1027	0.0528	0.0954
Feeder Cattle -Live Cattle	*0.8531**	0.0495	*0.8458**	0.0315	*0.8436**	0.0332
Γ2 - Correlation Regime 2.						
Corn -Soybean	*0.6413**	0.0776	*0.6282**	0.1101	*0.3876**	0.0978
Corn -Feeder Cattle	0.0054	0.0829	0.0343	0.0972	0.0423	0.0962
Corn - Live Cattle	-0.0115	0.0812	-0.0243	0.0797	0.0371	0.0854
Soybean - Feeder Cattle	0.0689	0.0876	0.0740	0.1045	0.1475	0.1057
Soybean - Live Cattle	0.0546	0.0859	0.0390	0.0886	0.0837	0.0834
Feeder Cattle -Live Cattle	*0.3333**	0.0891	*0.3099**	0.0769	*0.2763**	0.1198
γ or β - Betas						
probability beta - b11	*0.4787**	0.1280	5.3203	4.5990	2.7061	2.7526
probability beta - b21	*0.6593**	0.2325	5.7466+	3.1743	-4.3872	7.5435
probability beta - b12	0		-2.3792	2.0615	-0.4660	0.4294
probability beta - b22	0		-2.3603+	1.2650	0.5651	0.7039

* Significant at 5% level
+ Significant at 10% level

Table 5: Estimated Betas - Unrestricted Model between September 2003 and August 2008

UN_Restricted Model

	Constant Transition Probability (by DP)	**Standard Error**	***State Dependent Probability Ratio Sybn/Corn Price***	**Standard Error**	***State Dependent Probability Ratio USE_Stock***	**Standard Error**
Likelihood	*-2413.9*		*-2400.1*		*-2389.8*	
Γ1 - Correlation Regime 1.						
Corn -Soybean	*0.8336**	0.0521	*0.8421**	0.0496	*0.8744**	0.0417
Corn -Feeder Cattle	-0.3123	0.1968	*-0.3483**	0.1013	*-0.3776**	0.0956
Corn - Live Cattle	-0.1206	0.0885	-0.1290	0.0863	-0.1182	0.1130
Soybean - Feeder Cattle	-0.2558	0.1629	*-0.2869**	0.0946	*-0.3691**	0.0912
Soybean - Live Cattle	-0.1553+	0.0846	-0.1558+	0.0821	-0.1286	0.0975
Feeder Cattle -Live Cattle	*0.7895**	0.0815	*0.7858**	0.0458	*0.8044**	0.0368
Γ2 - Correlation Regime 2.						
Corn -Soybean	0.1703	0.1421	*0.2249**	0.0996	*0.3043**	0.0765
Corn -Feeder Cattle	-0.0843	0.2003	-0.0414	0.1194	-0.0774	0.0956
Corn - Live Cattle	0.0826	0.1078	0.1071	0.1037	0.0747	0.0994
Soybean - Feeder Cattle	*0.2249**	0.1028	*0.2306**	0.0681	*0.1943**	0.0582
Soybean - Live Cattle	0.2667*	0.0732	*0.2525**	0.0785	*0.1663**	0.0650
Feeder Cattle -Live Cattle	*0.2574**	0.1071	*0.2568**	0.0970	*0.3256**	0.0963
γ or β - Betas						
probability beta - b11	*0.7018**	0.3219	3.7835	3.4828	-2.8750+	1.6413
probability beta - b21	*0.6152**	0.3330	*11.1565**	3.9360	*-11.5949**	3.1140
probability beta - b12	0		-1.2262	1.4274	0.3431+	0.2031
probability beta - b22	0		*-4.4292**	1.6277	*1.2793**	0.3779

* Significant at 5% level or less

\+ Significant at 10% level or less

Table 6: Change in Conditional Probabilities of remaining at Regime 1[17] or remaining at Regime 2,for a certain change in corn's use to stock ratio.

Coefficients			Expansion Term		Value	% Δ corn 'use to Stock' ratio…. 5%	10%	15%	25%
$\bar{x}$	:	8.349				**produces Δ Probability…**			
b11	:	-2.875	$\frac{b_{12}*exp(b_{11}+b_{12}*\bar{x})}{[1+exp(b_{11} + b_{12}*\bar{x})]^2}$	:	0.085766	0.036	0.072	0.107	0.179
b12	:	0.343				***increase in prob. of remaining in Reg. 1***			

Coefficients			Expansion Term		Value	% Δ corn 'use to Stock' ratio…. 5%	10%	15%	25%
$\bar{x}$	:	8.349				**produces Δ Probability…**			
b21	:	-11.595	$\frac{b_{22}*exp(b_{21}+b_{22}*\bar{x})}{[1+exp(b_{21} + b_{22}*\bar{x})]^2}$	:	0.261421	0.109	0.218	0.327	0.546
b22	:	1.279				***increase in prob. of remaining in Reg. 2***			

17 i.e. $\Delta P(\Delta_t = 1 | \Delta_{t-1} = 1,\ x_{t-1})$ or $\Delta P(\Delta_t = 2 | \Delta_{t-1} = 2,\ x_{t-1})$

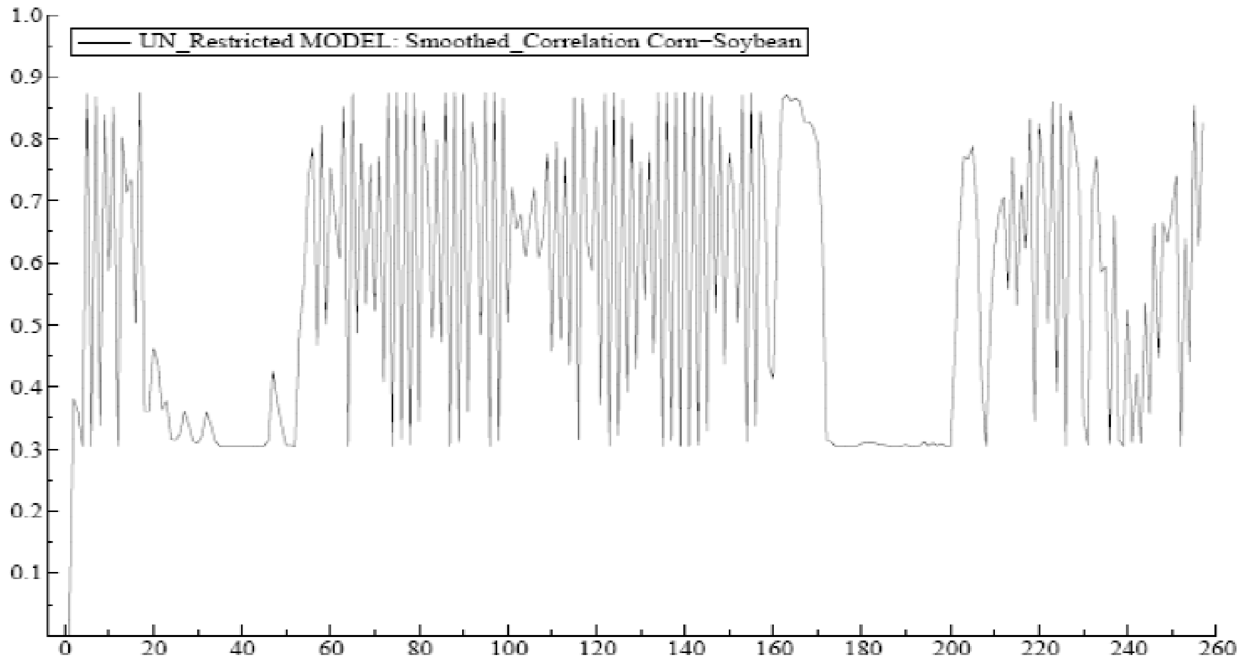


Figure 9.1: Smoothed Dynamic Correlations between Corn and Soybeans with *State Dependent transition probabilities* – considering 'use to stock' ratio; Sept. 2003 to Aug. 2008.

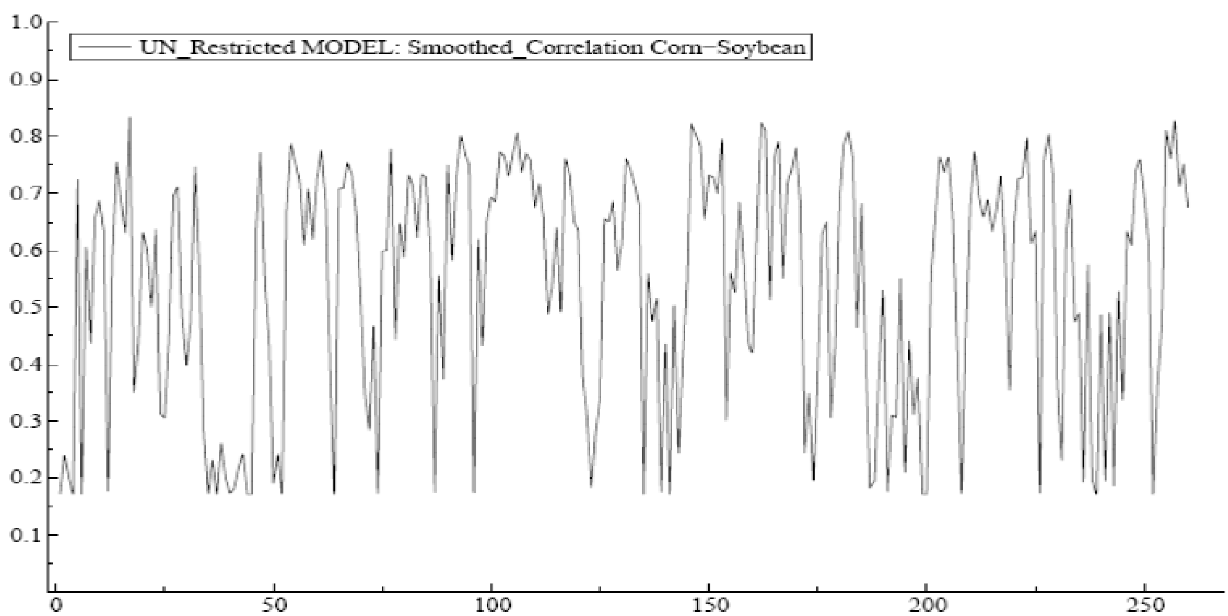


Figure 9.2: Smoothed Dynamic Correlations between Corn and Soybeans with *Constant transition probabilities*; from September 2003 to August 2008 (weekly).

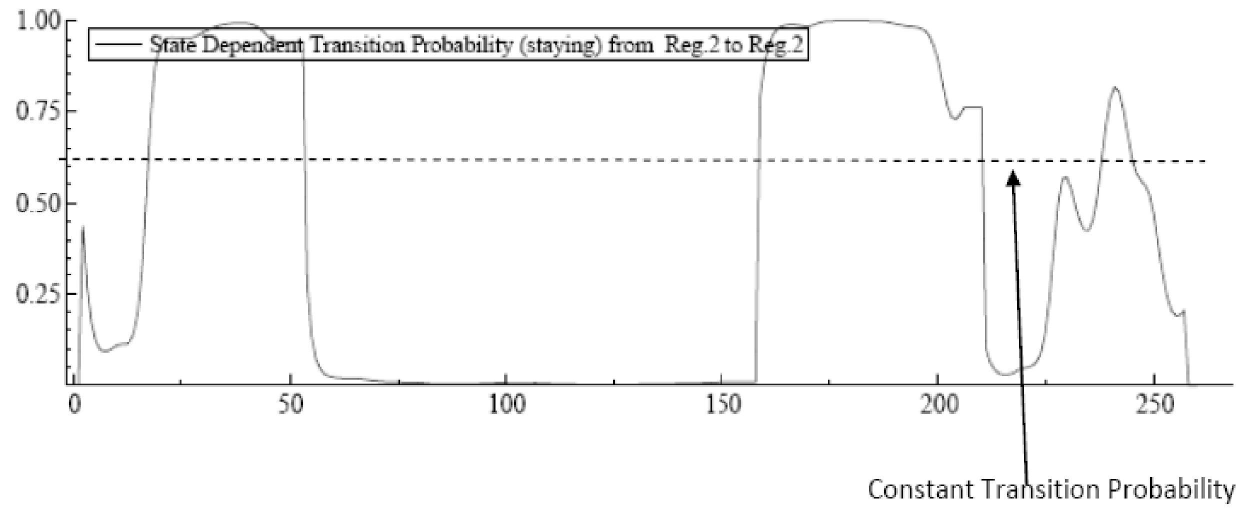


Figure 10.1: *Conditional State Dependent Transition Probability* of Remaining at Regime 2 with 'use to stock' ratio as weakly exogenous variable. i.e. $P(\Delta_t = 2 \mid \Delta_{t-1} = 2\,, \boldsymbol{x_{t-1}}; \beta_1)$ versus *Constant Transition Probability* of Remaining at Regime 2.

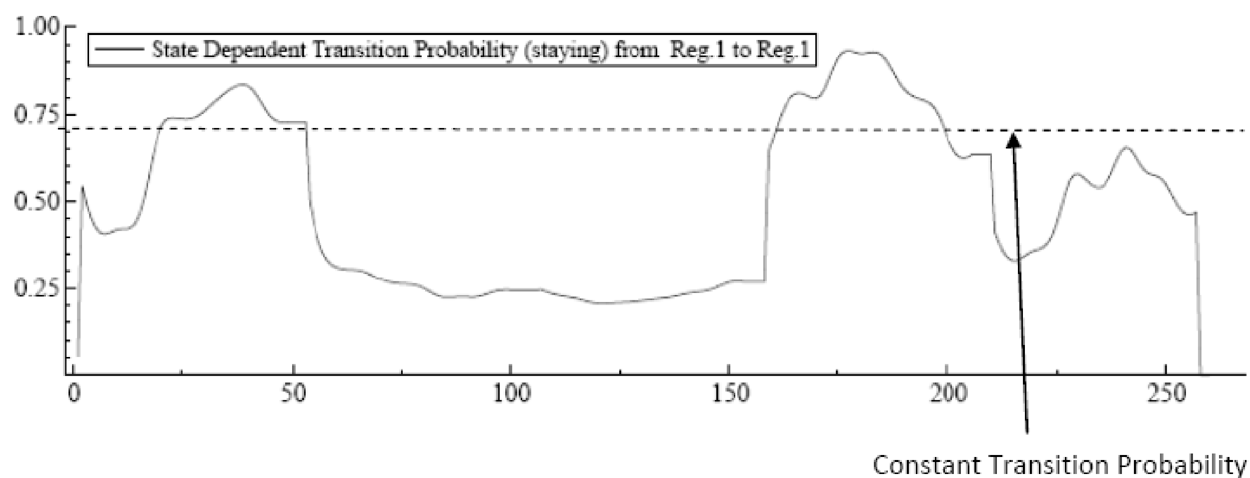


Figure 10.2: *Conditional State Dependent Transition Probability* of Remaining at Regime 1 with 'use to stock' ratio as weakly exogenous variable. i.e. $P(\Delta_t = 1 \mid \Delta_{t-1} = 1\,, \boldsymbol{x_{t-1}}; \beta_1)$ versus *Constant Transition Probability* of Remaining at Regime 1.