DROUGHT, BIOFUEL, AND LIVESTOCK

by

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(Under the Direction of Cheolwoo Park)

ABSTRACT

The effects of droughts are estimated for three major livestock market (beef, pork, and poultry) prices and two major related agronomy market (corn and soybeans) prices along with ethanol prices. Results indicate summer droughts have a significant positive effect on prices of corn, soybeans, and beef. Also, the linkages among the markets are investigated with results indicating in both the short- and long-run there are no price impact effects across crop and livestock markets. These results support the conclusion of Environmental Protection Agency that a waiver relaxing the ethanol-fuel mandate would have minimal impact on crop and livestock prices.

INDEX WORDS: climate, cattle, corn, drought, ethanol, hog, livestock markets, poultry, soybean

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DEDICATION

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CHAPTER 1

INTRODUCTION

The production of U.S. fuel ethanol, with a potential to improve energy security and the environment, has increased steadily in this century. However, this increased production has raised concerns about the lack of corn available to end users; chiefly livestock producers[1].Prior to the U.S. ethanol surge, approximately 75% of corn production was consumed as livestock feed. This percentage has dropped to approximately 40%, as corn is increasingly being used for ethanol production (Capehart, 2013; Tejeda, 2012).

The U.S. Midwest drought in 2012 has escalated the debate concerning available corn supplies, corn prices, and the consequences to end users. After August 2012, beef prices rose from $4.94 per pound in July to a record in March 2013 of $5.30 per pound (USDA, 2013). The diversion of corn to ethanol production coupled was the drought was blamed by the popular press and livestock industry for this price spike. In 2012, the weighted-average farm price for corn was $7.10 per bushel compared with $6.22 in 2011 (USDA, 2013). Such price spikes have a marked impact on livestock producers. This has spawned various governmental policies and programs for addressing this price volatility. One such policy proposed by ten state governors and livestock groups requested a partial waiver of the Renewable Fuel Standard (RFS) mandates (Doering, 2012). Their underlying rationale for the waiver is that relaxing the ethanol fuel

1.A byproduct of ethanol is distillers' dried grains (DDGS) that can be sold as fodder for livestock. A third of the grain used in ethanol production comes out as DDGS. Each bushel of grain for ethanol production produces 2.8 gallons of ethanol, 18 pounds of DDGE, and 18 pounds of carbon dioxide (Ethanol.org, 2013). In general, a metric ton of DDGS can replace1.22 metric tons of feed consisting of corn and soybean meal. .As a consequence, the use of DDGS in the feed market mitigates somewhat the impacts of increased corn use for ethanol (Hoffman and Baker (2011).

mandate would lead to lower corn prices for livestock producers by reducing the amount of corn used in ethanol. In November 2012, the U.S. Environmental Protection Agency (EPA) denied their waiver. The EPA stated the 2012 drought created hardships on the livestock sector, however, in reviewing the data; the EPA found in most cases a waiver would have minimal impact on corn, food, or fuel prices. Thus, the agency concluded the RFS would not cause severe economic harm to states and regions, which is a legislative requirement for a waiver. In the long-run, the markets can respond to this corn-price spike. It is projected if U.S. 2013 corn production returns to normal production, corn prices will spiral downward (Stewart, 2012).With normal production, corn prices could fall by $2.10 to $5.50, from a high of $7.60, the largest ever year-to-year drop (Huffman, 2013).The underlying EPA justification for not shifting policy by relaxing the mandate is acceptance that market forces in the long-run will correct any short-run price divergence. Implicit in this decision is the mandate should not be a policy tool for mitigating the short-run economic and market effects of corn-price volatility. It is important to maintain the ethanol mandates to provide for long-run ethanol market demand. However, lacking is this EPA policy is any programs explicitly directed toward mitigating the short-run price volatility. A comprehensive policy addressing both the short- and long-run fuel ethanol market appears to be warranted.

Before such a comprehensive policy can be developed, an understanding of the short- and long-run relations among the ethanol, corn, and livestock markets are required. Specifically, the linkages of ethanol prices on the livestock sector (beef, pork, poultry) are investigated with consideration of corn and soybean prices. Considering market prices allow investigation of both the demand and supply market effects as opposed to an investigation of production quantities which only consider the supply sides. The aim is to investigate both the short- and long-run relationships among these markets along with drought impacts by employing time-series price data. Based on these empirical results, an outline of a comprehensive policy can be articulated. A unique feature of this analysis is a first attempt at linking drought impacts on crop, livestock, and biofuel markets. The hypothesis is that agricultural production processes are only efficient within a certain climatic environmental range. Too wet or too dry will decrease production and increase the prices of agronomic commodities. The analysis will aid to better understand climatic impacts on biofuel and livestock markets.

The underlying hypothesis is that strong demand for ethanol production has resulted in higher corn prices which provide incentives for increased corn production. In many cases, farmers have increased corn acreage by adjusting crop rotations between corn and soybeans, which has caused soybean plantings to decrease. Other sources for increased corn plantings include pasture, fallow land, acreage returning to production from expiring Conservation Reserve Program contracts, and shifts from other crops, such as cotton (Capehart, 2013). There is a general trend of corn supply increasing from 10,578 million bushels in 2003 to 14,774 million bushels in 2010, around 4,200 million bushels, while the food, alcohol, and industrial use of corn only increased from 2,335 million bushels to 5,939 million bushels, around 3,600 million bushels (USDA, 2013). In addition, dried distillers grains with soluble (DDGS), a byproduct of ethanol production can be used in feed for livestock, including cattle, poultry, and swine. With non-ruminant poultry and swine animals, the use of DDGS is restricted given digestion limitations.

In Chapter 2, the literature is summarized. Then in Chapter 3, data used in the research are listed along the summary of statistics. Cointegration results are shown in Chapter 4, then drought effects, and inter-linkage among the markets are shown in Chapter 5. Conclusion and policy implications are in Chapter 6.

CHAPTER 2

LITERATURE REVIEW

The literature concerning ethanol-related transmission impacts is rapidly expanding (Campiche et al., 2010; Chang and Su, 2010; Zhang et al., 2010; Serra and Zilberman, 2013). General results indicate corn is the major driver behind other related commodities, including ethanol and soybeans. Although there is research introducing climate impact into corn markets, climate's impact on biofuel and livestock markets is far from fully considered (Differnbaugh et al., 2012).

Diffenbaugh et al. (2012) project 21st century changes in temperature and precipitation, simulate the response of U.S. corn yields, and use a Global Trade Analysis Project (GTAP) model to simulate the volatility in corn prices. Their research concludes that U.S. corn-price volatility will increase sharply in response to global warming projected over the next three decades. However, their analysis is limited in terms of only investigating the impact of climate (indexed by temperature and precipitation) on corn-price volatility. The possible spillover effects in the livestock market are not addressed. Their analysis could be extended by investigating the mechanisms of how climate affects agricultural and biofuel markets. The time-series model developed in the next section is an attempt to understand these mechanisms.

In contrast to extensive literature on ethanol-market effects on crop commodity prices, their effects on livestock markets have not been as widely investigated. Tejeda (2012) used a multivariate regime-switching model and found significant positive dynamic correlations among weekly price changes of DDGS and corn and soybean meal. Various time-series models are used to investigate the dynamic interaction among agronomy and livestock prices (Anderson et al., 2008; Pozo et al.,2012;Tejeda and Goodwin, 2009; Tejeda and Goodwin, 2011). Miljkovic, et al.

(2012) employ a simultaneous equations model and determine a possibility of ethanol policy indirectly impactingcattle production through the RFS's influence on corn quantity.Bhattacharya, et al. (2009) and Elobeid, et al. (2006)used a multi-market equilibrium displacement model to account for the interdependence. Six markets are considered: beef, pork, poultry, corn, ethanol, and ethanol byproducts.

However, the literature is void on accounting for drought and its impacts on agricultural and biofuel markets. The relation of drought, biofuel, and livestock is still elusive. As a first attempt to fill this void, the transmission effects among the markets by including drought effectsand ethanol prices are investigated.

CHAPTER 3

DATA

For the ethanol-fuel market, U.S. real ethanol prices are obtained from the Energy Information Administration (EIA)from August 2004 to October 2011. Nominal corn, soybean, beef, pork, and poultry spot prices are acquired from the Commodity Research Bureau (CRB).Nominal prices are adjusted by the Bureau of Labor Statistics Consumer Price Index, with 1982-1984 as the baseline year.

The drought variable is acquired from U.S. Drought Monitor, a synthesis of multiple indices and impacts, which represents a consensus of federal and academic scientists[2]. The Drought Monitor concept was developed (jointly by the National Weather Service, the National Drought Mitigation Center, and the U.S. Department of Agriculture's Joint Agricultural Weather Center in the late 1990s) as a process that synthesizes multiple indices, outlooks, and local impacts, into an assessment that best represents current drought conditions. No single definition of drought works for all circumstances, so a drought index is employed to detect and measure droughts (Drought Monitor, 2013). The index was designed to heighten awareness of drought through a single product by labeling drought by intensity from D1 to D4 with D1 being the least

[2]Only drought in Midwest is chosen, because only the drought has impact on corn will be considered as drought. The same idea can be used to explain why d1d4 is chosen, rather than d0d4. According to table 1, the definition of the D0 is the lowest level of drought, which is not severe enough to have agronomic impacts.

intense and D4 being the most intense. Drought intensity categories are based on five key indicators, including the Palmer drought index, soil moisture, stream flow, precipitation, short and long-term drought indicator blends, and numerous supplemental indicators based on regional and seasonal characteristics (North American Drought Monitor, 2013). The accompanying drought severity classification indicating ranges for each indicator for each dryness level is listed in table 1. For the analysis, the percentage of area that falls into the category of D1 and above is used as the indicator of drought. With the objective of capturing major weather effects on crop yield, the drought variable is truncated to June and July by setting the other monthly observations to zero.

Table 1. Drought Severity Classification

Category	Description	Possible Impacts	Palmer Drought Index	CPC Soil Moisture model (Percentiles)	USGS Weekly Streamflow (Percentiles)	Standardized Precipitation Index (SPI)	Objective Short and Long-term Drought Indicator Blends (Percentiles)
D0	Abnormally Dry	Going into drought: short-term dryness slowing planting, growth of crops or pastures. Coming out of drought: some lingering water deficits; pastures or crops not fully recovered	-1.0 to -1.9	21-30	21-30	-0.5 to -0.7	21-30
D1	Moderate Drought	Some damage to crops, pastures; streams, reservoirs, or wells low, some water shortages developing or imminent; voluntary water-use restrictions requested	-2.0 to -2.9	11-20	20-Nov	-0.8 to -1.2	11-20
D2	Severe drought	Crop or pasture losses likely; water shortages common; water restrictions imposed	-3.0 to -3.9	6-10	10-Jun	-1.3 to -1.5	6-10
D3	Extreme drought	Major crop/pasture losses; widespread water shortages or restrictions	-4.0 to -4.9	3-5	5-Mar	-1.6 to -1.9	3-5
D4	Exceptional Drought	Exceptional and widespread crop/pasture losses; shortages of water in reservoirs, streams, and wells creating water emergencies	-5.0 or less	0-2	0-2	-2.0 or less	0-2

Source: drought monitor. http://droughtmonitor.unl.edu/classify.htm

Table 2 lists the summary statistics for the real price series. After log transformation, the Augmented Dickey Fuller tests for all the price series indicate the inability to reject the presence of a unit root at a 5% significance level. This suggests the presence of non-stationary price series, which motivates the use of a vector error correction model (VECM) model.Jmulti will be used to run the data.

Table 2. Summary Statistics

	Mean	Std. Dev	Skewness	Kurtosis	Minimum	Maximum	ADF test P-value
Pe	1.037	0.211	0.800	4.512	0.647	1.858	0.407
Pc	183.187	67.407	0.688	2.549	90.236	350.874	0.700
Ps	428.072	124.469	0.281	1.883	250.858	735.802	0.610
Pb	43.653	3.478	0.372	2.986	36.523	54.583	0.094
Ph	32.103	5.210	0.091	2.440	21.447	46.781	0.052
Pp	37.957	2.060	-0.604	2.429	33.333	41.384	0.405
D1D4	21.031	7.729	0.199	3.037	0	41.73	0.385

Note: Pe is price of ethanol, Pc price of corn, Ps price of soybean, Pb price of beef, Ph price of hog, Pp price of poultry. All the prices are adjusted by CPI. ADF test is the Augmented Dickey Fuller test.

CHAPTER 4

COINTEGRATION

As discussed by Engle and Granger (1987), a linear combination of two or more non-stationary series that share the same order of integration may be stationary. If such a stationary linear combination exists, the series are said to be cointegrated and the linear combination is referred to as a long-run equilibrium relationship. Although there may be short-run dynamics that can cause the series to deviate from the equilibrium, there exists VECM, which adjusts the deviation and ties the individual series together.

The VECM can also be extended to include exogenous variables. Inclusion of these variables prevents a prohibitively large number of parameters from being estimated (Gary, 1995). This is accomplished by the following VECM with exogenous variables (Lütkepohl, H. and Krätzig, 2004):

$$\Delta y_{i,t} = \alpha\beta' y_{i,t-1} + \sum_{1}^{6}\Gamma_i \Delta y_{i,t-1} + \Phi x_{(t-4)} + dD_t + u_{i,t}$$

where y is a vector of ethanol, corn, soybean, beef, pork, and poultry prices, and x is a vector of drought, drought squared, and a dummy summer variable, $\alpha$the long-run speed of adjustment, $\beta' Y_{i,\,t-1}$is the error correction term, which is also called cointegration equation, Γ indicating short-run inter-linkage among Y variables, ϕ the effect of x, d the effect of dummy variable, which is summer here, μ the error term, Δ means the first differenced. The summer variable, consisting of July and August is included to capture possible impactsassociation withhigher summer meat production and consumption.In order to determine appropriate lag orders, p, and rank number, s,for subsequent models, the model selection criteria Akaike information criterion

(AIC)and Schwarz Bayesian information criterion(SBC) are employed. Both indicate choosing a two period (week) lag, with the Johansen's trace test indicating a one cointegrating relationship(Zibin Zhang, et al.,2010).

$$(1)Pe = \underset{(0.41)}{0.67Pc} + \underset{(0.56)}{0.19\ Ps} - \underset{(0.39)}{3.87Pb} + \underset{(0.83)}{1.97Ph} + \underset{(1.33)}{5.43Pp} + \underset{(470.14)}{2758.94}$$

wherePe, Pc, Ps, Pb, Ph, and Pp arethe log transformed prices of ethanol, corn, soybeans, beef, pork, and poultry, respectively. Standard errorsin the parentheses indicate all the coefficients are significant at the 1% level except for the prices of corn and soybean, which are significant at only the 11 and 73% level, respectively. There is no significant a long-run price relation between ethanol and agronomic commodity markets (corn and soybeans). This result is consistent with Zhang et al. (2010), employing a VECM in examining the relation between fuel prices (ethanol, gasoline, and oil) and agricultural commodity prices (corn, rice, soybeans, sugar, and wheat), who indicate commodity prices in the long run are neutral to fuel price changes. However, there is a long-run relation between livestock and ethanol prices.

The existence of cointegrationamong the ethanol and livestock price series indicates a long-run causality in at least one direction among the prices, but it does not indicate the direction of the causality. Such causality direction can be determined with a VECM, which specifies the short-run dynamics of each price in a framework that anchors the dynamics to the long-run equilibrium relationship (cointegrate). The actual time period of the short-run depends on the nature of the dynamics among the prices. Calculating the impulse response functions provides an indication of the short-run length.

CHAPTER 5

VECM RESULTS

The effects of drought on prices are captured in the VECM assuming a quadratic effect on the agricultural markets. Mcphail et al. (2012) found within one month, any speculative demand impacts on agronomy prices are mainly accounted for. In accordance with their results, employing droughtlagged two periods (weeks) was specified with an expectation of it having a significant impact on agricultural prices. When drought occurs within two weeks, corn and soybean prices are affected through the commodities future markets. The vector error correction results with the drought effect are reported in Table 3. Deletion of any first three and last three observations yields the same results in terms of both magnitudes of coefficients, and significance levels, indicating the robustness of the results.

Table 3. Results of VECM

	D_Pe	D_Pc	D_Ps	D_Pb	D_Ph	D_Pp
drought	0.034	-0.522**	-0.354*	-0.239*	-0.186	0.011
	(0.156)	(0.257)	(0.213)	(0. 132)	(0.270)	(0.046)
drought^2	-0.003	0.010*	0.008*	0.005**	0.004	0.000
	(0.003)	(0.005)	(0.004)	(0.003)	(0.006)	(0.001)
summer	0.932	5.035*	2.019	2.082	1.411	-0.290
	(1.688)	(2.777)	(2.302)	(1.424)	(2.911)	(0.500)
ECT	-0.014***	-0.003	-0.005	-0.014***	0.009	-0.006***
	(0.005)	(0.008)	(0.007)	(0.004)	(0.009)	(0.001)
D_Pe	0.405***	-0.088	-0.090	0.059	0.036	-0.013
	(0.047)	(0.078)	(0.065)	(0.040)	(0.082)	(0.014)

D_Pc	0.078**	-0.003	0.123**	0.000	-0.047	0.004
	(0.040)	(0.066)	(0.055)	(0.034)	(0.069)	(0.012)
D_Ps	-0.031	-0.044	-0.081	-0.024	0.008	-0.011
	(0.047)	(0.078)	(0.065)	(0.040)	(0.082)	(0.014)
D_Pb	-0.026	0.085	0.016	-0.065	-0.022	0.072***
	(0.062)	(0.102)	(0.085)	(0.052)	(0.107)	(0.018)
D_Ph	-0.018	-0.009	-0.028	-0.028	0.065	-0.026***
	(0.032)	(0.052)	(0.043)	(0.027)	(0.055)	(0.009)
D_Pp	-0.164	-0.128	0.089	-0.005	-0.093	-0.012
	(0.169)	(0.278)	(0.231)	(0.143)	(0.292)	(0.050)
Constant	0.333***	0.054	0.105	0.327***	-0.236	0.137***
	(0.118)	(0.198)	(0.162)	(0.100)	(0.205)	(0.035)

Note: Standard Errors are in parenthesis. * , **, and *** denote significance at the 10% level, 5% level, an 1% level, respectively. ECT denotes the error correction term. D_Pe is first differenced logrithm adjusted price of ethanol, D_Pc first differenced logrithm adjusted price of corn, D_Ps first differenced logrithm adjusted price of soybean, D_Pb first differenced logrithm adjusted price of beef, D_Ph first differenced logrithm adjusted price of hog, D_Pp first differenced logrithm adjusted price of poultry.

Drought Effects

The results listed in table 3 indicate that drought has a significant (at the 10% level) convex effect on prices of corn, soybeans, and beef. This reflects the condition that at first a drought has little impact on prices, but after a point drought will have a positive significant impact on prices. The results also indicate that corn is the least sensitive to drought. Drought has a positive impact on corn prices after 25% of the land area is affected. This is in contrast to soybean prices, which are affected only after 20%. A possible explanation is the tropical origins of corn, so it can tolerate exposures to brief adverse temperatures as high as 112 ^{o}F, but soybeans are a temperate legume with an ideal daytime temperature of 85°F. When air temperatures exceed 85°F, soybeans can experience heat stress with associated yield reductions, especially when soil moisture is limited(Lindsey.L, et al., 2012). In terms of beef, a major feed is grass, which is directly affected by drought conditions. As most cattle are raised by grass until autumn, any drought occurring during the summer months will impact their growth.

Notably absent is the lack of a significant influence of drought on ethanol, pork, and poultry prices. At least in the short run (two weeks) the results indicate drought is not significantly affecting these prices. As opposed to the crop and beef markets, these markets appear to be insulated from short-run drought market disturbances.

Inter-Linkage among the Markets

In addition to the drought effects, significant short-run inter-linkages among the markets are also listed in Table 3. For ease of interpretation, according to Zibin Zhang (2010), the associated Granger causality are listed in Table 4. In the short-run, beef prices are positively influencing poultry prices at the 1% significance level; whereas, pork prices are negatively influencing them, again at the 1% level. Poultry appears to be a substitute for beef, given this positive relation between the prices. It is a little more difficult to explain the negative impact of a rise in pork prices on poultry prices, but the coefficient, although significant, is relatively small. In the short run, corn prices are Granger positively influencing soybean and ethanol prices at the 5% significance level. In the long run, this positive relation in corn and soybean prices may be capturing a crop rotation effect. However, in the short run, it is probably caused by some joint speculative demand or an underlying variable driving both of the price series. As a major input in ethanol production, an increase in corn prices will in the short run positively influence ethanol prices, but consistent with past literature not in the long run. The competitive nature of the corn market yields a supply respond and corrects any short-price disequilibrium.

As indicated in Table4,an ethanol price change does not precipitate a short-run price effect on agricultural markets. However, it may have a long-run relationship with livestock markets. In the long run, livestock market prices (beef, pork, and poultry) are influencing ethanol prices with ethanol price shocks also influencing beef and poultry. In contrast, the crop markets (corn and soybean) do not appear to have this long-run relation with ethanol prices. This is consistent with recent literature indicating possible short-run agronomy and ethanol impacts, but no long-run impacts (Qiu et al., 2012; McPhail, 2011,2012; Nazlioglu et al., 2013; Saghaian, 2010). Before a definitive long-run link between ethanol to the livestock markets can be established, further investigation is warranted. Investigations both in terms of possible theoretical relations and further empirical analyses are required. Preliminary inquiry may suggest pork prices influencing ethanol, beef, and poultry prices in long-run may be the result of its international linkages. U.S. pork exports are over 15% of production, and thus, pork prices are sensitive to global economic conditions (MEF, 2013). Pork prices could be serving as a surrogate for latent global economic activity variables. Strong positive economic activity generally simulates expanding agricultural commodity demand with associated rising prices. With the pork price as an economic indicator, ethanol, beef, and poultry prices have long-run positive responses to its shock.

Table 4. Granger Price Causalities

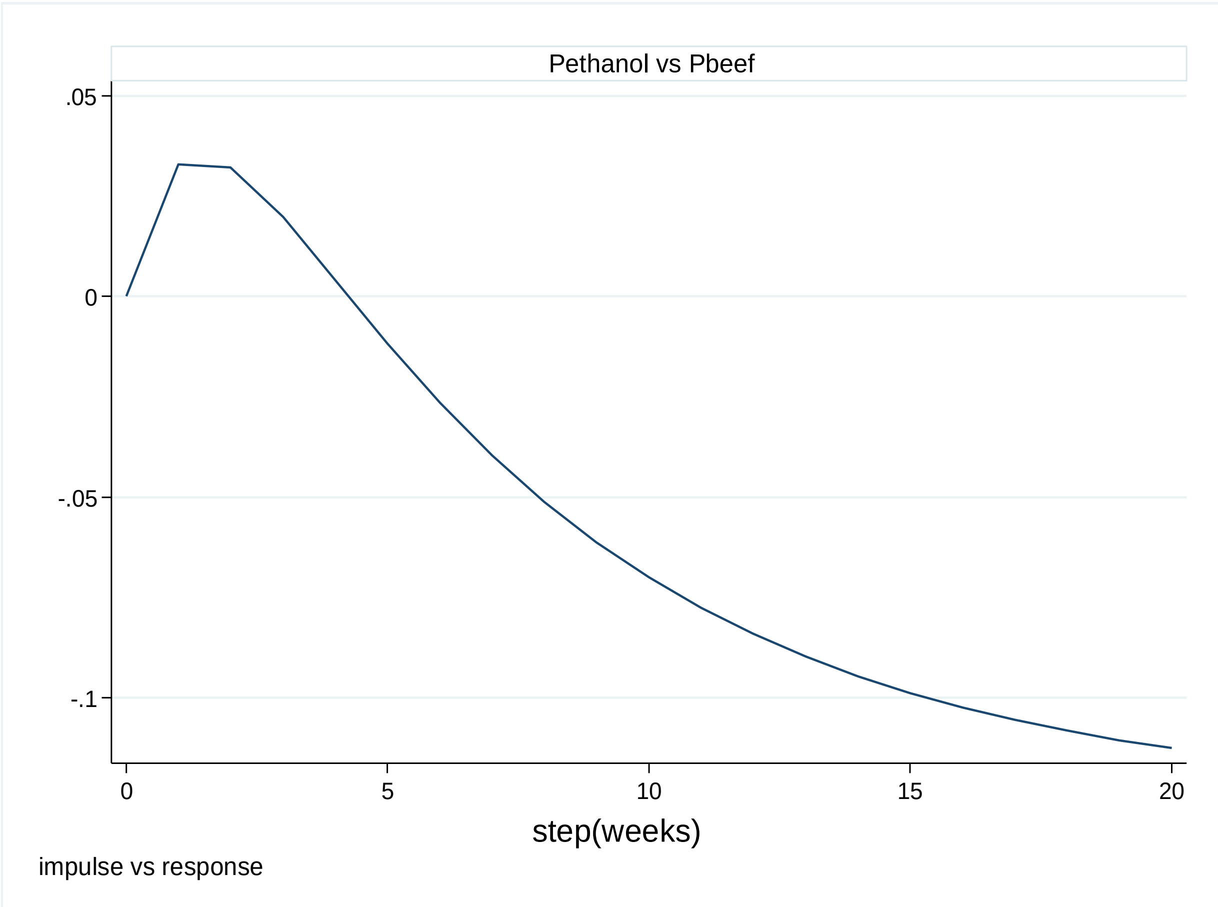
Short-run	Long-run
Beef → poultry	hog → ethanol/ beef /poultry
Hog →poultry	poultry↔ beef
Corn →soybean	poultry ↔ ethanol
Corn →ethanol	beef ↔ ethanol

The limited if any causal relation between the agronomy and livestock markets is further indicated by the forecast error variance decomposition.   Granger causality reported in Table 4 does not indicate the magnitudes of these causal linkages. For such determination, variance-decomposition, listed in Table5, provides information on the relative magnitude of the causation influence of one price series on another. Specifically, decomposition reflects the percentage of the variance associated with each price in the VECM caused by shocks to the other prices. As indicated in Table5, the livestock (agronomy) market prices have no influence on the variability of agronomy (livestock) prices, which supports the lack of any causal relations between these two markets. Furthermore, the magnitude of the influence ethanol prices have on agronomy and livestock price is limited, less than 5%. Only the magnitude of the influence that corn prices contribute to the variance for soybean, 43%, is above 5%. This indicates other forces are contributing to the price variability in the agronomy, livestock, and ethanol markets. Consistent with these forecast error variance decomposition results, the impulse response functions indicate minor impacts from a one standard-deviation shock of a given price on the other price series.

Table 5. Forecast Error Variance Decomposition after Ten Periods (weeks)

Forecast Error Variance Decomposition	Pe	Pc	Ps	Pb	Ph	Pp
Pe	0.92	0.02	0	0.03	0.02	0.01
Pc	0.02	0.98	0	0	0	0
Ps	0.01	0.43	0.56	0	0	0
Pb	0	0	0	0.93	0.05	0.02
Ph	0.01	0	0	0.01	0.98	0
Pp	0.05	0.01	0	0.02	0.1	0.82

Figure 1. Impulse Response Functions of Pethanol and Pbeef



As to residual analysis, the regular portmanteau test is not used for VECM with exogenous variables(Helmut L¨utkepohl, et al., 2006). An alternative way is to use LM-Type test, which shows that under 5% significance level, there is no autocorrelation within 5 lags.

CHAPTER 6

CONCLUSIONS

The 2012 drought brought again to the forefront the issue of ethanol's production-impacts on corn and livestock prices. The EPA denial of a RFS waiver to decrease the ethanol mandate following the drought is based on the belief the current mandates will have minimal impact on corn and livestock prices. Considering the environmental drought and price relations among the crop (corn and soybean), livestock (beef, pork, and poultry), and ethanol markets, the empirical results support this belief. The EPAs acceptance that market forces in the long-run will correct any short-run price divergence caused by drought or other external impacts is supported by the empirical results. The linkages among corn, ethanol, and livestock markets are estimated, which reveal both the direction and magnitude of impacts within and among these markets.

As a first attempt in linking drought impacts on agronomy, livestock, and biofuel markets, the Drought Monitor index was employed to measure drought intensity. This index included soil moisture, stream flow, and precipitation and was incorporated into a VECM. The results indicate a long-run relation between the livestock and ethanol markets, with a corresponding neutral relation with agronomy markets. As hypothesized, the results support EPAs belief that in the long run the market will correct any possible short-run corn/ethanol price disturbances. One such disturbance is drought with the results indicating a positive effect on the prices of corn, soybeans, and beef with prices increasing at an increasing rate with drought severity. Other short-run results indicate corn prices are influencing ethanol prices.

These results can serve as a foundation for justifying policies directed toward mitigating any negative market-price volatility. The impact of drought on increasing the volatility of agronomy and beef prices suggests policies may be warranted toward reducing this short-run price volatility. Such policies could take the form of precautionary private and public agricultural commodity buffer stocks, continuous infusion of public sponsored research and outreach, food diversity, and reducing regional trade restrictions.

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