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Fertilizer, Natural Gas, and Corn: A Case of a Price Switching Regime

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Abstract

This study looks at changing relationships among ammonia, natural gas, and corn spot prices. Prices from April 2001 to May 2014 were tested for correlation, causation, and cointegration. Evidence of a regime switch is found during December 2007. Before this date natural gas prices Granger caused changes in fertilizer price, while after this date corn price Granger caused changes in the price of fertilizer. Johansen's test found evidence of cointegration among the data leading to the use of a vector error correction model to estimate relationships among ammonia, natural gas, and corn prices. Results indicate that a regime shift did occur around December of 2007.

Keywords: corn prices, fertilizer prices, natural gas prices, cointegration, correlation, vector error correction model.

1. Introduction

Natural gas is the primary input used in the production of nitrogen fertilizer. In the early 2000's, during a period low margins, contraction, and consolidations in the nitrogen fertilizer manufacturing industry, the price of natural gas and nitrogen fertilizer followed each other closely (Huang 2007; and Huang 2009). Since 2007, corn prices have moved closely with nitrogen fertilizer prices. Causes of this switch may have been higher corn prices resulting, in part, from the Renewable Fuel Standard (RFS) that mandates the use of biofuels in the United States and market concentration within the nitrogen fertilizer industry.

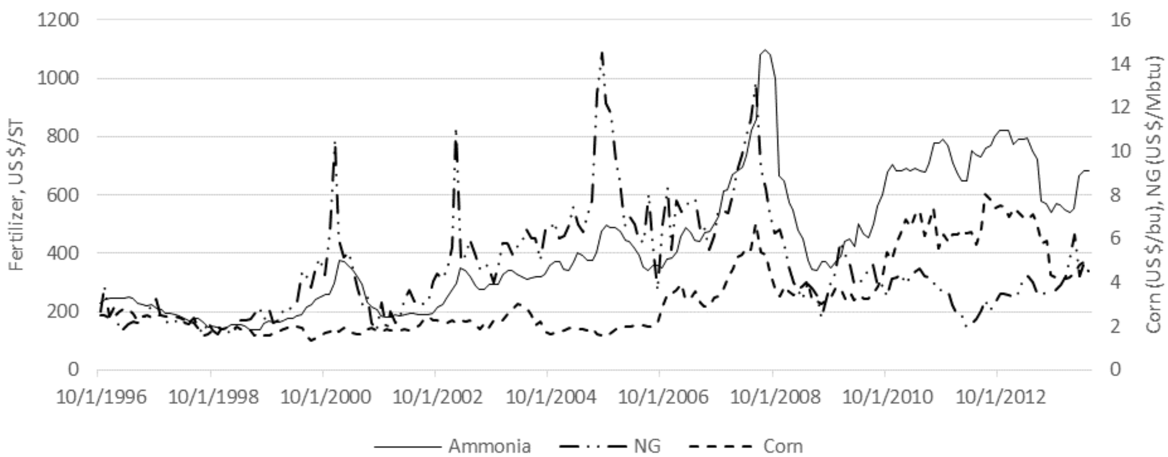
Energy and environmental policy, especially the Renewable Fuel Standard, increased the use of corn-based ethanol and the demand for corn following its passage in 2005 (e.g., Solomon et al, 2007; Balat and Balat, 2009; Schnepf and Yacobucci, 2010). This increase led to a period of historically high corn prices. As corn prices rose so did its marginal revenue product.

Nitrogen fertilizer is a key input for many agricultural crops. During the past fourteen years, fertilizer, including nitrogen fertilizer, prices have been volatile. This issue is of special concern for corn farmers who use significantly more fertilizer relative to soybean and wheat crops. Huang et al. (2009) find this amounts to an average application cost of $93 (in 2007) per acre for corn growers. Thus, relatively speaking, volatile ammonia fertilizer prices for corn growers create a higher relative concern for price uncertainty. One such cause of this price volatility in the last decade is attributed to energy costs (Lambert and Miljkovic, 2010).

Huang (2007) found that corn and nitrogen fertilizer had relatively low correlation of 0.07 to 0.17 prior to the year 2000. However, between the periods of 2000 on into 2007, Huang finds these two commodities follow a much higher price correlation of 0.7 to 0.8. Huang conducted a cointegration analysis and found the two have a measure of 0.8, suggesting long-run trends are quite responsive to price shocks.

After 2007, fertilizer prices appear to follow the price of corn. The price of corn increased significantly following the implementation of the RFS policies (e.g., Miljkovic et al., 2012; Taheripour et al., 2010). Figure 1 displays the historic weekly prices for fertilizer, natural gas, and corn over the period of 2-April 2001 to 19-May 2014. A close look at the figure, ammonia fertilizer (GCFPAMMC) and natural gas (NGUSHHUB) spot prices follow similar movements near the beginning. Again, fertilizer prics appears to have a closer relationship with corn price (CORNIASC).

Figure 1. Monthly Corn, Fertilizer, and Natural Gas Spot Prices, October 1996-May 2014



Tests exist to confirm these relationships. Furthermore, additional research (beyond the scope of this study and not presented here) into other specific events are able to shed some light onto reasons for movements within the series. One possible reason stems from natural gas, and other energy sources, which saw drastic increases in prices within the 2006 to 2008 period (Lambert and Miljkovic, 2010). Post 2008, however, natural gas prices fell below pre-2006 prices. This is possibly due to a rapid increase in tight oil and natural gas production within the United States made possibly by horizontal drilling and hydraulic fracturing (e.g., Brown and Yücel). This volatility creates implications within crop and commodity pricing, further drawing uncertainty in regards to input prices for corn and other agricultural products. If fertilizer is pricing itself to energy inputs, then corn producers, elevators, and others, need to analyze and forecast prices based upon price time series other than the direct series for fertilizer in order to gain full information for decision making in planting and risk management.

The objective of this study is to determine if and when a possible regime switch occurred between ammonia, natural gas, and corn. This is achieved by testing for the presence of correlation, causality, and cointegration among these prices. Then the relationships among these prices is estimated using vector autoregression (VAR) model or vector error correction model (VEC), if cointegration is found.

2. Data

Monthly time series data for U.S. spot prices of corn, anhydrous ammonia and urea, and natural gas from April 2001 to May 2014 were obtained from the USDA, Green Markets, and Bloomberg. Spot prices are used instead of futures to avoid the unwanted influence of speculation including excessive volatility that does not explain actual market clearing equilibriums and cross effect relationships (Gardebroek and Hernandez, 2013). Table 1 displays estimated Pearson correlations among variables. All correlations are significant at the 1 percent level. Little correlation is found between the natural gas and fertilizer prices when considering the data across the entire period.

Table 1. Corn, Fertilizer, and Natural Gas Pearson Correlation Coefficients

Confirmation for use of Ammonia over Urea. 4/2001 - May/2014

	UREA NOLA	*UREA Corn Belt*	*Ammonia Corn Belt*	*Iowa SC Corn Spot*	*Henry Hub NG Spot*
UREA NOLA	1.0000				
UREA Corn Belt	0.9894	1.0000			
AMMONIA Corn Belt	0.8855	0.9210	1.0000		
Iowa SC Corn Spot	0.7474	0.7574	0.8240	1.0000	
Henry Hub NG Spot	0.1628	0.1552	0.1069	-0.2366	1.0000

Note: Pearson coefficients. All are statistically significant at 1 percent.

Correlations are used to determine appropriate data series and time periods for our analysis. In addition, the hypotheses of cointegration, correlation, and causation between fertilizer and natural gas switching to fertilizer and corn needs some statistical backing for the time periods chosen. Tracking Correlation changes over time helps to identify the point where relationships "switch"[1]. Of course, correlation does not necessarily imply causation nor cointegration, and vice-versa.

The correlation analysis considered 4, 16, 26, and 52-period moving correlation plots. Volatility of the higher-frequency correlations, however, appears to be too large to determine the approximate point in time the switch occurred. Thus, f the correlation frequency period is expanded. In this case, a 104-period correlation analysis of monthly data is chosen as the resulting plots appear to indicate relationship "switching" beginning around in December 2007. This provides an approximate, and statistically appropriate, point in time when the relationships change. Figure 2 displays the moving 104-period correlations between the variables.

[1] Prices are analyzed over returns (Log differencing) as the resulting series proves the correlations are insignificant and hardly noticeable in possible measuring any relation. See Appendix A.1 for further explanation and the resulting correlation table.

Figure 2. 104-period, moving correlations, May 2003-May 2014

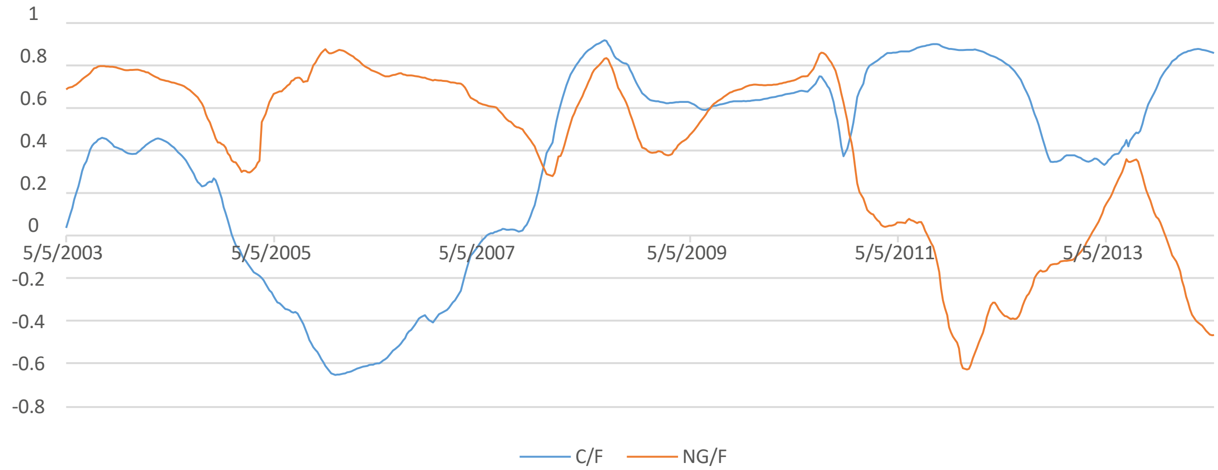
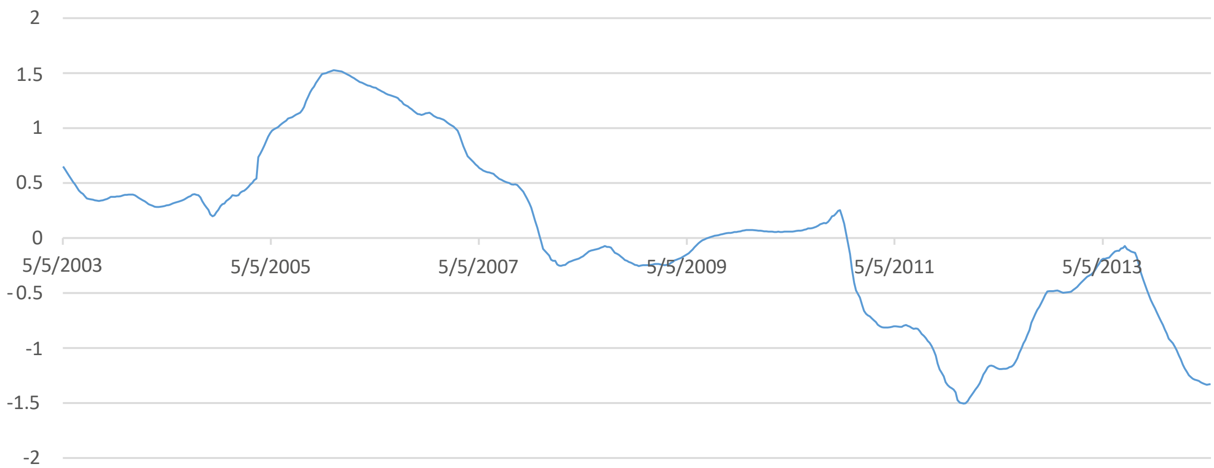


Figure 3. Difference of Correlations, May 2003 – May 2004



The 104-period plot allows for visual and mathematical difference analysis. Plotting the pair of correlations over time, along with subtracting the correlation value of corn-fertilizer from natural gas-fertilizer yields a graph[2], Figure 3, that appears to indicate the approximate date when fertilizer is priced to corn (its product), rather than natural gas (its input). As one can see, fertilizer was correlated with natural gas of a higher relative magnitude prior to around December of 2007 over corn. After this date, fertilizer appears to be more correlated with corn, thus the "switch" of pricing power.

With the two periods identified, further correlation analysis of each period is conducted to confirm a "switch" within the series. Gardebroek and Hernandez (2013) use a similar correlation approach to identify changes in correlations of weekly price returns among oil, ethanol, and corn. Figure 4 presents data prior to the switch, when fertilizer and natural gas have a

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[2] Gas-fertilizer chosen as the lead over corn-fertilizer since higher correlation measure existed prior to the switch.

higher correlation. Figure 5 presents data after switch when fertilizer and corn have a higher correlation.

Figure 4. Monthly Fertilizer and Natural Gas Spot Prices, April 2001-December 2007

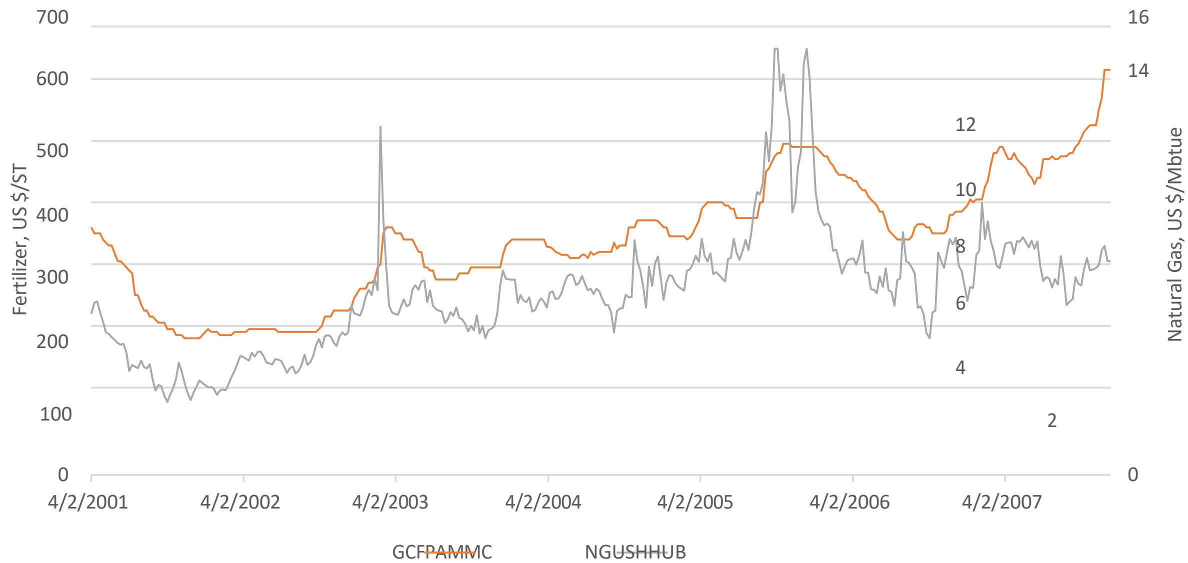

Figure 5. Monthly Fertilizer and Natural Gas Spot Prices, December 2007-May 2014

Table 2 presents correlation estimates and statistical support for the hypothesis that fertilizer prices itself to its product (corn), rather than its input (natural gas). Notice the strength of correlation between corn price and fertilizer price increases 54.8%, whereas the strength of fertilizer price and natural gas price decreases 58.98% between the two periods. Over the thirteen year period, corn price generally has a stronger correlation with fertilizer than natural gas price.

Table 2. Corn, Fertilizer, Natural Gas Spot Price Correlations, 2001-2014

Pearson correlations of weekly spot prices, 2001-2014

	Apr 2001 through Dec 2007			Dec 2007 through May 2014			Total Sample		
	Corn	Ammonia	Natural Gas	Corn	Ammonia	Natural Gas	Corn	Ammonia	Natural Gas
Corn	1.0000			1.0000			1.0000		
Ammonia	0.4012***	1.0000		0.6209***	1.0000		0.8240***	1.0000	
Natural Gas	0.1224**	0.7660***	1.0000	-0.1264**	0.3142***	1.0000	-0.2366***	0.1069***	1.0000
Number of observations:			342			327			669

Note: Statistically significant at 5 percent (**) and 1 percent (***).

3. Methodology

The presence of a unit root is tested to determine if the time series is nonstationary. Granger causality is tested to determine the presence of causality and endogeneity. A cointegration verification, which determines if the integrated variables within the model contain a linear relationship between themselves, is then conducted. Two methods are further used to estimate these relationships, vector autoregression (VAR) and vector error correction model (VECM). The later, VECM, extends the VAR by incorporating error correction variables/terms accounting for long-term relations between or among the series.

3.1 Testing for Unit Roots

Augmented Dickey Fuller (ADF) tests (Dickey and Fuller, 1979) are conducted to determine the presence of non-stationarity. The results are presented in Table 3. The ADF test take the constant and trend as exogenous. Optimal lag lengths are determined using the Schwartz Information Criterion (SIC) minimization technique. A lag of 4 is chosen for fertilizer prices; however, corn and natural gas do not exhibit lags beyond the current spot price. Natural gas price is the only variable that exhibits stationarity at the 5% significant level. The analysis finds that all three variables are non-stationary and exhibit a constant and trend at the 1% significance level.
First differencing is implemented to produce random-walk generating processes. ADF tests confirm stationarity at $I(1)$ for all three variables at a 1% significance level. Since all three series are integrated of the same order, a Johansen multivariate cointegration test is conducted.

Table 3. ADF Unit Root Test Results

ADF Unit root tests: Results on levels and first differences.

	Lag Length [a]	*Exogenous Variables*	*ADF statistic (levels)*	*Prob.* [b]	*ADF Statistic (first diff).*	*Prob.* [b]
Corn Spot	0	Constant and trend	-2.2331	0.4698	-28.1325	0.0000
Fertilizer Spot	4	Constant and trend	-2.9833	0.1377	-9.4692	0.0000
Natural Gas Spot	0	Constant and trend	-3.4951	0.0407	-8.2719	0.0000

[a] Optimal lag length determined automatically by Schwartz Information Criterion within Eviews 7.
[b] MacKinnon (1996) one-sided p-values.

3.2 Granger causality

Consideration of causation aids in the decision of whether a variable is considered exogenous or endogenous. Furthermore, error correction and cointegration are equivalent representations given the Granger representation theorem (Enders, 2010; Shaik and Miljkovic, 2010). A Granger Causation test (Granger, 1969) finds and supports the switching observation results presented in Table 4. The results indicate natural gas price Granger causes fertilizer price before 2007. Likewise, it is found that corn price Granger causes fertilizer price after 2007. With the price of natural gas and corn exhibiting Granger causality in different periods, it is intuitive that the variables are treated as exogenous within these respective periods. Causation from the other variables is tested; however, the results are insignificant. All price variables are assumed to be endogenous variables within the model. The results of the Granger causality tests provide additional support for the switching pricing regime hypothesis.

Table 4. Pairwise Granger Causality Test Results

Pairwise Granger causality tests (4 lags).

	4/2001 - 12/2007 338 obs.		12/2007 - 5/2014 323 obs.	
Null hypothesis	*F-Statistic*	*Probability*	*F-Statistic*	*Probability*
Fertilizer Price does not Granger Cause Corn Price	1.3361	0.2562	0.4756	0.7537
Corn Price does not Granger Cause Fertilizer Price	1.6457	0.1624	2.0859	0.0825*
Natural Gas Price does not Granger Cause Corn Price	0.2397	0.9157	0.5237	0.7184
Corn Price does not Granger Cause Natural Gas Price	0.2168	0.9290	1.1570	0.3298
Natural Gas Price does not Granger Cause Fertilizer Price	6.8941	0.0000***	1.6519	0.1611
Fertilizer Price does not Granger Cause Natural Gas Price	1.2785	0.2782	0.7605	0.5516

Statistically significant at 10 percent (*), and 1 percent (***) levels.

3.3 Cointegration and VAR/VEC Methodology

Next, the presence of cointegration is estimated. The results are used to decide whether a VAR or VEC model is appropriate. A VAR model is preferred in that standard OLS assumptions are sufficient while VEC models address endogenity among variables with long-run linear interrelations.

3.3.1. Cointegration

In order to determine which estimation procedure to conduct, VAR or VEC, the possible existence of a long-run time-series relationship of the system needs to be determined. Variables that possess a unit root, are non-stationary, become so with the same order of integration (i.e. all of the series are of order $I(d)$), then there is a possibility that a linear relationship potentially exists and a VEC model is preferred (Lambert and Miljkovic, 2010). Johansen's multivariate cointegration test (Johansen, 1991; Johansen and Juselius, 1995) can determine if a combination exists for vector of linear trends within the long-run relationship between fertilizer, natural gas, and corn. If cointegration is not present, or if the variables in question are stationary (i.e. $I(0)$ order), then a VAR model is appropriate (Enders, 2010).

3.3.2 VAR/VEC estimation

A vector autoregression (VAR) model is used to estimate long-run explanatory coefficients. The mathematical representation of a VAR is

$$y_t = A_1 y_{t-1} + \cdot \cdot \cdot + A_p y_{t-p} + BX_t + \varepsilon_t \quad (1)$$

where $\boldsymbol{y_t}$ is a k vector of endogenous variables, $\boldsymbol{x_t}$ is a d vector of exogenous variables, $\boldsymbol{A_1}, \ldots, \boldsymbol{A_p}$ and $\boldsymbol{B}$ are vectors of coefficients to be estimated, and ε_t is a vector of innovations that may be contemporaneously correlated but are uncorrelated with their own lagged values and uncorrelated with all the right-hand side variables. Since only lagged values of endogenous variables appear on the right-hand side of the equations, simultaneity is not an issue and ordinary least squares (OLS) yields consistent estimates. Moreover, even though the innovations εt may be contemporaneously correlated, OLS is efficient and equivalent to generalized least squares since all equations have identical regressors (Hamilton 1994; Enders 2010; Shaik and Miljkovic, 2010).

When cointegration exists within the system, a vector error correction model, as defined by Enders (2010), and Shaik and Miljkovic (2010), is preferred. The noticeable difference between the VAR and VEC is the inclusion of a linear combination of the variables, creating a method to correct for long-run equilibrium deviations with an error correction term. In the presence of cointegration and a non-zero error correction term existence, then the latter is the measure of a speed-of-adjustment, i.e., the rate at which the endogenous variable corrects for errors and deviations from equilibrium between the variables within the system (Shaik and Miljkovic, 2010).

4. Results

This section presents cointegration results and the vector error correction model estimates that explain long-run relationships among the price of fertilizer, natural gas, and corn.

4.1. Johansen Test for Cointegration

The system of variables examined in this study are believed to have long-run relationships. The presence of this relationship for each time period is tested using the Johansen multivariate cointegration test (Johansen, 1991; Johansen and Juselius, 1994). The results are presented in Table 5.

Tests indicate that a cointegrating vector occurs before 2007 at the 5% significance level. The tests also suggest that there is one cointegrating vector after 2007 at the 5% significance level for maximum eigenvalue test and one at the 10% significance level for the trace test.

Table 5. Johansen Cointegration Test Results

		4/2001 - 12/2007		
Hypothesized number of cointegrating equations	*Eigenvalue*	*Trace/max-eigenvalue statist*	*Critical value (0.05*	*Prob.***
Unrestricted Cointegration Rank Test (Trace)				
None *	0.0708	36.8708	35.0109	0.0312
At most 1	0.0314	12.1296	18.3977	0.2995
At most 2	0.0041	1.3949	3.8415	0.2376
Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
None *	0.0708	24.7412	24.2520	0.0431
At most 1	0.0314	10.7347	17.1477	0.3330
At most 2	0.0041	1.3949	3.8415	0.2376
		12/2007 - 5/2014		
Unrestricted Cointegration Rank Test (Trace)				
None	0.0833	34.4170	35.0109	0.0578
At most 1	0.0168	6.3993	18.3977	0.8363
At most 2	0.0030	0.9602	3.8415	0.3271
Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
None *	0.0833	28.0177	24.2520	0.0151
At most 1	0.0168	5.4391	17.1477	0.8676
At most 2	0.0030	0.9602	3.8415	0.3271

Both Trace and Max-eigenvalue tests indicate 1 cointegrating equation at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
** MacKinnon-Haug-Michelis (1999) p-values

4.2. VEC Model Estimation Results

The VEC model is performed in two different periods to "determine statistical significance and duration of exogenous shocks" (Lambert and Miljkovic, 2010), on spot prices for fertilizer, corn, and natural gas. For series that exhibit a stationary process, i.e., unit root did not exist, a general vector autoregressive (VAR) model is appropriate (Miljkovic and Mostad, 2007). Given the ADF tests results, the Schwartz Information Criteria (SIC) finds 4 lags to be used in the error correction estimation. Results of the VEC before and after 2007 are presented in Tables 6 and 7.

Table 6. Vector Error Correction Model Estimates, May 2001-December 2007.

Results: VEC estimates for 4/2001 - 12/2007 336 obs. after adjustments

Error Correction	Natural Gas Price (*g*)	Fertilizer Price (*f*)	Corn Price (*c*)
Cointegration equation (1)	-1.5343 ***	7.5256 ***	-0.0055
Diff (f_{t-1})	-0.0177 ***	-0.6717 ***	-0.0016 **
Diff (f_{t-2})	-0.0100	-0.3255 ***	-0.0013
Diff (f_{t-3})	-0.0072	-0.1719 **	-0.0016 *
Diff (f_{t-4})	0.0034	-0.1805 ***	-0.0003
Diff (g_{t-1})	0.4541 ***	-4.5108 ***	0.0093
Diff (g_{t-2})	0.4357 ***	-2.8950 **	0.0109
Diff (g_{t-3})	0.2927 ***	-2.1174 **	0.0074
Diff (g_{t-4})	0.1709 ***	-0.8808	0.0031
Diff (c_{t-1})	-0.1998	-5.6340	-0.9623 ***
Diff (c_{t-2})	-0.0614	-2.2270	-0.7867 ***
Diff (c_{t-3})	0.1947	-5.6902	-0.4445 ***
Diff (c_{t-4})	0.0498	0.0513	-0.0693
Constant	0.0025	0.1133	0.0015
R^2	0.5562	0.4529	0.5201
Adjusted R^2	0.5383	0.4308	0.5008
Sum of squared residuals	182.1345	20448.9500	3.7013
S.E. equation	0.7521	7.9691	0.1072
F-statistic	31.0404	20.5044	26.8477
Log likelihood	-373.8859	-1167.0040	280.6544
Akaike information criterion	2.3088	7.0298	-1.5872
Schwarz information criterion	2.4679	7.1888	-1.4282
Mean dependent	0.0012	0.0149	0.0005
S.D. dependent	1.1068	10.5628	0.1517
Determinant resid covariance (dof adj.)		0.4083	
Determinant resid covariance		0.3593	
Log likelihood		-1258.3390	
Akaike information criterion		7.7580	
Schwarz criterion		8.2692	

Note: Statistical significance at the: 10% (*), 5% (**), and 1%(***) levels.

Table 7. Vector Error Correction Model Results, December 2007, May 2014

Results: VEC estimates for 12/2007 - 5/2014	321 obs. after adjustments		
Error Correction	Natural Gas Price (*g*)	Fertilizer Price (*f*)	Corn Price (*c*)
Cointegration equation (1)	-0.0032 **	0.2519 ***	-0.0084 ***
Diff (f_{t-1})	-0.0022 **	-0.7107 ***	-0.0015 **
Diff (f_{t-2})	-0.0017	-0.5636 ***	-0.0010
Diff (f_{t-3})	-0.0004	-0.4608 ***	-0.0015 **
Diff (f_{t-4})	0.0007	-0.1696 ***	-0.0005
Diff (g_{t-1})	-0.9624 ***	-5.5833 *	0.0209
Diff (g_{t-2})	-0.6333 ***	-6.0581	0.0504
Diff (g_{t-3})	-0.3195 ***	-3.3915	0.0622
Diff (g_{t-4})	-0.2139 ***	4.7104	0.0588 *
Diff (c_{t-1})	0.5068 ***	-30.6919 ***	0.1550
Diff (c_{t-2})	0.4267 ***	-26.2396 ***	0.1392
Diff (c_{t-3})	0.2546 **	-17.4825 **	0.0982
Diff (c_{t-4})	0.2186 **	-9.0532	0.0455
Constant	0.0013	-0.0851	-0.0007
R^2	0.5368	0.4237	0.4847
Adjusted R^2	0.5171	0.3993	0.4629
Sum of squared residuals	57.5414	209356.60	22.7908
S.E. equation	0.4329	26.1140	0.2725
F-statistic	27.3623	17.3607	22.2168
Log likelihood	-179.5900	-1495.5760	-30.9431
Akaike information criterion	1.2062	9.4055	0.2800
Schwarz information criterion	1.3707	9.5699	0.4445
Mean dependent	0.0010	0.0000	-0.0009
S.D. dependent	0.6230	33.6927	0.3718
Determinant resid covariance (dof adj.)		9.1408	
Determinant resid covariance		7.9962	
Log likelihood		-1700.1120	
Akaike information criterion		10.8730	
Schwarz criterion		11.4017	

Note: Statistical significance at the: 10% (*), 5% (**), and 1%(***) levels.

Focusing on the dynamics of the shock innovations, labeled *cointegration equation (1)* for each table, the procedure estimates and confirms statistical significance and magnitude for fertilizer within the system. The null hypothesis is that the cointegrating vector has no effect on the endogenous variables. Resulting speed of adjustment coefficients indicate that the null is rejected in all cases; hence there is long-term relationship among the three prices. The results find fertilizer price is positively impacted by shocks at the 1% significance level. Pre-2007 estimates of 7.5256 are much larger than post-2007 estimates of 0.2519. This indicates a faster adjustment towards the long run equilibrium of the fertilizer price through the co-movement interrelations of the three prices prior to 2007. The estimate for the pre-2007 natural gas price cointegration equation is -1.5343 and is significant at the 1% level. The post2007 estimate is significant at the 5% level with a value -.0032 indicating a slower adjustment towards to equilibrium.

Fertilizer price lags are statistically significant at the 1% level for all four lags (weeks) in after 2007. Prior to 2007, lags are significant at the 1% for one, two, and four week lags, while the 3-period lag variable is significant at the 5% level. Estimates of natural gas and corn price impacts on fertilizer prices from this model are consistent with Granger causality test results, yet the signs at the first glance appear to be inconsistent with expectations. Pre-2007, changes in the natural gas prices lead to an inverse impact on fertilizer prices for up to three periods, i.e., weeks. It is important to recall, however, that the long-run positive relationship between these two prices is positive and presented as the speed of adjustment coefficient, while these instant, short-term impacts of the high-frequency data are more instantaneous signals. Corn prices have no short term impacts on fertilizer prices in this period. Similar reasoning could be used to interpret the fertilizer equation coefficients post-2007 period. Here, corn price short-run impacts on fertilizer prices are significant and negative, while the long-run relationship is positive and significant, as expressed by the speed of adjustment coefficient. Natural gas price impacts on fertilizer price is significant only with one-lag consideration.

The model also finds that natural gas prices adjust downward over long-run, as indicated by the speed of adjustment coefficients, in co-movement with fertilizer and corn prices. Yet, pre-2007 short-term impacts of these prices on natural gas price is non-existent with the exception of one lag period. Yet, corn price positive impacts natural gas prices for up to three lag periods. A possible explanation for this phenomenon is the increase in ethanol price due to increase in corn price, and as ethanol is produced out of corn in the United States, and the two energy sources are substitutes in consumption, to some extent (Taheripour et al., 2010).

The lags two through four of fertilizer has no significance for the natural gas equation, with only the 1-period lag having significance at the 1% and 5% levels for the pre- and post-12/2007 eras. Finally, the estimated equation for corn yields similar significance as the natural gas equation. The 1-period lag of fertilizer is significant at the 1% level for both equations. The 3-period lag is significant at 10% and 5% levels for pre- and post-12/2007 eras, respectively. This suggest that fertilizer price increases are not being passed-through to the next level in supply chain.

The analysis shows that prior to 2007 natural gas prices had a large significant impact on the price of fertilizer and that a switch occurred after this time where corn price impacted fertilizer price.

5. Conclusions

This paper studies the relationship among fertilizer, natural gas, and corn prices. Historical monthly spot price data from April 2001 into May 2014 obtained from Bloomberg is used. Granger causality and Johansen cointegration tests are used to identify an approximate point in time for the apparent structural break with statistical evidence. Granger causality identifies that fertilizer is Granger caused by natural gas through 2007, then by corn after that date. Further confirmation of unit root and a system of variable series which are stationary at the same integrated order reveals the need to use a vector error correction model.

There is evidence that fertilizer[3] prices experience an econometrically significant structural change. As producers seek to operate by maximizing profits and minimize operating costs, they need to continually be proactive in monitoring how their operational inputs and outputs impact their goals. This paper finds after 12/2007, the fertilizer market tends to price itself to corn. In this case, it would be more appropriate to anticipate changes in fertilizer input costs by looking at how the corn price market is reacting, i.e., corn farmers should anticipate fertilizer price changes by which their own product prices change. Prior to 12/2007, the natural gas market would dictate fertilizer price, thus providing incentive for corn growers to look at the natural gas market instead of the fertilizer market to see how their input costs will impact their overall operations.

Possible caveat of this study includes unaccounted presence of The Great Recession of 2008 and 2009 that likely impacted these prices as well. Accounting for such a shock is difficult with weekly data. Thus, this research focused solely on determining relationship periods and what measureable outcomes can be achieved to aid in better understanding for price uncertainty and risks in this vertical chain of commodities. Further research and methods should be employed to include such possible patterns within the data, as well as other farm and governmental policies which were enacted within the period.

Operating on the cost margin aids in securing risk, as long as the costs are predictable. With the ever increasing volatile energy prices (as natural gas is in this case), challenges for some producers who rely upon such energy intense products can see even more uncertainty and risk. Here it is found that fertilizer producers must notice not only prices of fertilizer, but the prices found within fertilizer's own production process, to exhibit trends that follow close to their own input and output prices.

[3] It is likely other producer commodities in this time period not studied within this paper experienced such structural changes as well.

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Appendix

A.1. Price Returns

An analysis on the returns of price movements is conducted by correlation comparison, as similar to the analysis on volatility between energy and food prices provided by Gardebroek and Hernandez (2013). Take into consideration, while observing the low measures of correlation among the returns to prices (Table A.1), when comparing with the correlations of prices in Table2. Note the difference here is correlations of returns are not highly correlated, nor statistically significant by Pearson measures, within the split periods. While this is notable and something to be taken into consideration upon further analysis, however, these movements (i.e. Logarithmic differences or returns on prices) that are non-correlated doesn't necessarily mean they have no relationship at the price level. As Table 2 shows, the prices themselves are highly correlated for the periods in question. Thus, this research continues further analysis beginning with level spot prices since that is the level of correlation to determine other relationship measures.

Table A.1
Pearson correlations of the first difference (returns) of weekly spot prices, 2001-2014

	Apr 2001 through Dec 2007			Dec 2007 through May 2014			Total Sample		
	Corn	Fertilizer	Natural Gas	Corn	Fertilizer	Natural Gas	Corn	Fertilizer	Natural Gas
Corn	1.0000			1.0000			1.0000		
Ammonia	-0.0018	1.0000		0.0832	1.0000		0.0531	1.0000	
Natural Gas	0.0133	-0.0271	1.0000	0.1674***	-0.0324	1.0000	0.0897**	-0.0286	1.0000
Number of observations:	341			327			668		

Note: Statistically significant at 5 percent (**) and 1 percent (***).