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An Examination of Factors Influencing Fertilizer Price Adjustment
#10511

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Abstract

This paper utilizes an error correction model to examine how anhydrous ammonia (AA) and urea prices at different locations in North America adjusted to changes in crop and input prices during two time periods: 2002 to 2005 and 2006 to 2009. The empirical results suggest that natural gas futures prices had relatively more of an impact on nitrogen fertilizer prices during the 2002-2005 period. Nitrogen prices tended to adjust more rapidly to increases in natural gas futures prices than decreases. In the 2006 to 2009 period, corn futures prices had more of an impact on nitrogen prices. Nitrogen prices tended to respond immediately to decreases in corn futures prices. The nitrogen price responses to increasing corn futures prices were mixed.

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Contents

1. Introduction

The purpose of this paper is to compare how nitrogen fertilizer prices at different locations in North America have adjusted to changes in the prices of key demand and supply variables known to impact nitrogen prices. On the supply side, natural gas futures prices were used. Natural gas is a key input and significant variable cost in the production of nitrogen fertilizers. On the demand side, corn futures prices were used as a proxy for nitrogen fertilizer demand. Corn is a significant user of nitrogen fertilizers in the United States. Higher corn prices increase the incentive to plant corn, driving up the demand and price for nitrogen fertilizers. In addition, Western Canada is a significant exporter of nitrogen to the United States. Higher corn prices in the United States increase demand for Canadian nitrogen exports.

Recently, there has been considerable volatility in fertilizer prices. By the second half of 2008, wholesale nitrogen prices had risen rapidly to unprecedented levels. By the first half of 2009, however, prices had declined precipitously to price levels previously observed in 2006. This paper will examine how nitrogen prices responded to changes in factor prices during the relatively stable 2002 to 2005 period, as well as the highly volatile 2006 to 2009 period. The relative impact of each factor on the nitrogen price adjustment process will be examined for both periods.

2. Empirical Analysis

2.1 Methodology

The first step in the analysis is to test whether there exists a long run (cointegrated) relationship between nitrogen prices (anhydrous ammonia (AA) and urea) and factor prices (natural gas futures price and corn futures price). Univariate unit root tests were undertaken to test for stationarity using the Augmented Dickey Fuller Test. Non-stationary variables follow unit root processes. A consequence of non-stationarity is that the variance of the residuals is not constant over the sample period, violating the assumptions of independence and identical distributions. In order to avoid the bias associated with non-stationarity, transformations to the data must occur (Hendry and Juselius, 2000). A series that is not stationary in its levels, but becomes stationary after differencing *i* times, is said to be integrated of order *i*. If two price series share the same order of integration, one can test whether there is a linear cointegration vector linking the two series together over the sample period. Bivariate cointegration tests were conducted using the Johansen test.

The standard single equation model for examining price adjustment between cointegrated series is the error correction model (ECM). This study utilized an ECM based on Bettendorf et al. 2003, to examine how nitrogen prices adjusted to factor prices during the 2002 to 2005 period relative to the 2006 to 2009 period.

The first equation of the ECM specifies the relationship, in levels, between the fertilizer price and the factor price:

$$N_{k_i,t} = \delta + \gamma F_{m,t} + u_t \qquad (1)$$

Where $N_{k_i,t}$ is the price of nitrogen fertilizer type *k* at location *i* and $F_{m,t}$ is the price of factor *m*. The second equation models the fertilizer price adjustment process through short run price changes in factor prices and the adjustment to the long run disequilibrium in the price levels between the fertilize price and the factor price:

$$N\_PC_{k_i,t} = \sum_{l=0}^{p} \phi_l \, F\_PPC_{m,t-l} + \sum_{l=0}^{q} \rho_l \, F\_NPC_{m,t-l} + \lambda ecm_{t-1} + \upsilon_t \qquad (2)$$

Where $N\_PC_{k_i,t}$ is the change in price of nitrogen fertilizer type *k* at location *i*, F_PPC_m and F_NPC_m represent the positive and negative price changes for factor price *m*, respectively.[1] Factor prices were split into positive and negative price changes in order to compare the short run dynamics in the price adjustment process. Nitrogen prices may not respond to changes in factors prices within the same period as the factor price change. Therefore, lags of the positive and negative factor price change variables were included in the model. The length of the positive and negative lag for each factor price term was determined using the Akaike Information Criterion (AIC). The term ecm_{t-1} is the residuals lagged one period from *Equation (1)*, and serves as the error correction mechanism. The ecm_{t-1} coefficient λ is interpreted as the adjustment to the disequilibrium in the relative prices of the nitrogen price and the factor price. In addition, in order for the cointegration relationship between the fertilizer price and the factor price to hold, λ must be less than zero and statistically significant (Asche et al. 1999). As λ approaches negative one, the price adjustment process shortens.

2.2 Data

Weekly North American wholesale fertilizer prices for anhydrous ammonia (AA) and urea, for the period 2002 to 2009, were taken from the Green Markets Survey. The price locations for AA include: New Orleans/Lousiana (NOLA), Mid Cornbelt (MC), Northern Plains (NPL), Great Lakes (GL) and Western Canada (WC). For urea, the price locations include: New Orleans/Lousiana (GULF), MC, NPL, GL and WC. Prices for the US locations are in US dollars (USD), while the Canadian locations are in Canadian dollars (CAD) and all prices were converted to metric tonnes.[2] In addition, NYMEX Contract 1 weekly natural gas futures prices, in USD, and weekly CBOT Corn No.2 Yellow futures prices, in USD, were used for factor prices. Figures 1 and 2 compare AA prices and factor prices over the entire period of study. Figures 3 and 4 compare urea prices and factor prices over the same period. The figures show that nitrogen prices exhibited more

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[1] *F_PPC =F_PC* if *F_PC>0*, and *=0* otherwise. The reverse is true for F_NPC.

[2] For the Western Canada (WC) price equations, the exchange rate was added to control for exchange rate effects.

volatility in the 2006 to 2009 period. Natural gas futures prices were more volatile than corn futures prices in the 2002 to 2005 period, while corn futures prices were more volatile in the 2006 to 2009 period.

Table 1a provides correlation coefficients[3] between AA price locations and factor prices, for the two periods of study.

Table 1a: Correlation Coefficients: AA Prices and Factor Prices

	NOLA	MC	NPL	GL	WC
	2002-2005				
natgas	0.85	0.91	0.91	0.90	0.88
corn	-0.14	-0.19	-0.16	-0.18	-0.15
	2006-2009				
natgas	0.55	0.58	0.54	0.54	0.35
corn	0.64	0.73	0.72	0.71	0.64

Table 1a shows that during the 2002 to 2005 period, natural gas futures prices were strongly positively correlated with AA prices at all locations. Corn futures prices showed a weak, negative correlation with AA prices. However, during the 2006 to 2009 period, the positive correlation between natural gas prices and AA prices weakened significantly. In addition, the relationship between AA prices and corn prices reversed, from weak negative correlation to positive correlation exceeding the correlation between AA and natural gas futures prices at all price locations.

Table 1b provides correlation coefficients between urea price locations and factor prices, for the two periods of study.

Table 1b: Correlation Coefficients: Urea Prices and Factor Prices

	GULF	MC	NPL	GL	WC
	2002-2005				
natgas	0.81	0.86	0.87	0.85	0.87
corn	-0.28	-0.27	-0.26	-0.21	-0.16
	2006-2009				
natgas	0.61	0.58	0.56	0.56	0.37
corn	0.82	0.82	0.81	0.83	0.69

The almost identical trend occurred with urea prices. Table 1b shows that during the 2002 to 2005 period, urea prices were highly positively correlated with natural gas futures prices, while corn futures prices were weakly negatively correlated with urea prices. In the 2006 to 2009 period, the positive relationship between urea prices and natural gas

[3] Correlation coefficients range of values is 1 to –1, with 1 implying a perfect positive relationship, –1 implying a perfect negative relationship and 0 implying no relationship.

prices weakened, while the relationship between urea prices and corn futures prices reversed, from weak negative correlation to positive correlation exceeding the coefficients between urea and natural gas futures prices.

Table 2 provides the number of price changes for all prices for the two periods.

Table 2: Number of Price Changes

	2002-2005		2006-2009	
	Increases	Decreases	Increases	Decreases
AA - NOLA	46	21	26	26
AA - NPL	42	24	52	34
AA - MC	66	43	80	71
AA - GL	37	25	42	36
AA - WC	28	4	32	12
Urea - GULF	87	65	93	100
Urea - NPL	42	24	47	35
Urea - MC	72	46	76	78
Urea - GL	44	18	53	37
Urea - WC	27	8	32	10
natgas	107	91	123	82
corn	94	112	97	105

Table 2 shows that for both time periods, the locations with the highest frequency of nitrogen price changes were NOLA and MC for AA and GULF and MC for urea. WC had the lowest frequency of price change for AA and urea. There is also a tendency for there to be more price increases than decreases in almost every case. However, when you consider the period 2006 to 2009, the level of nitrogen prices at the beginning of 2006 and at the end of 2009 are very close, implying that the price increases were more gradual and price declines more immediate during the 2006 to 2009 period. Factor price changes show that natural gas futures prices and corn futures prices had more positive and negative price changes than nitrogen prices, with the number of price increases and decreases being roughly equal.

2.3 Results

Augmented Dickey-Fuller (ADF) tests were undertaken on all the variables in levels and first differences to test for the presence of unit roots. AIC criterion was used for lag selection. The ADF level and differenced test statistics, and the accompanying critical values, are provided in Table 3.

Table 3: Augmented Dickey Fuller Tests

	2002-2005		2006-2009	
	Price Levels (with trend)	First Differences (with constant)	Price Levels (with trend)	First Differences (with constant)
AA-NOLA	-3.244	-7.117**	-2.541	-3.7393*
AA-MC	-2.952	-5.044**	-1.248	-4.948**
AA-NPL	-3.24	-5.022**	-0.924	-7.257**
AA-GL	-2.861	-5.675**	-1.123	-4.687**
AA-WC	-2.881	-5.383**	-1.585	-9.909**
Urea-GULF	-3.333	-5.806**	-2.916	-4.199**
Urea-MC	-3.189	-5.842**	-2.187	-5.281**
Urea-NPL	-3.132	-7.809**	-2.02	-5.286**
Urea-GL	-3.425	-6.128**	-2.092	-4.651**
Urea-WC	-3.077	-5.438**	-1.545	-9.873**
natgas	-1.916	-6.562**	-2.108	-6.242**
corn	-1.991	-11.1**	-1.732	-7.066**

Critical values for price levels with trend are: 5% -3.436, 1% -4.006
Critical values for first differences with constant are: 5% -2.89, 1% -3.496
*** Indicates significance at 1% level, * Indicates significance at 5% level*

The results show that all variables are non-stationary in their levels but become stationary after first differencing. Therefore, each price series is integrated of order one I(1).

Bivariate cointegration tests were then performed using the Johansen test, to observe whether AA and urea prices were cointegrated with factor prices in both periods. Table 4a provides the trace statistics from the bivariate Johansen tests between AA prices and factor prices, as well as the corresponding critical values for one cointegrating vector.

Table 4a: Bivariate Johansen Cointegration Trace Statistics, AA and Factor Prices

	NOLA	MC	NPL	GL	WC
	2002-2005				
natgas	17.1885*	20.6712**	23.2238**	19.5316*	15.7537*
corn	6.2507	5.1877	4.7440	4.6901	5.7850
	2006-2009				
natgas	17.357*	21.6959**	21.9919**	24.0211**	15.4835*
corn	18.0715*	18.6207*	25.6434**	20.7374**	28.7079**

*Critical values for one linear cointegrating vector in a bivariate test, significant at 1% is 15.04 and at 5% is 20.04. * implies significance at 5%, ** implies significance at 1%*

The results for AA prices in Table 4a indicate that all AA prices and natural gas futures prices are cointegrated in both periods, while corn futures prices are only cointegrated with AA prices in the 2006 to 2009 period. The results from the cointegration tests are in line with the trends observed in the correlation coefficients.

Table 4b provides the trace statistics from the bivariate Johansen tests between urea prices and factor prices, as well as the corresponding critical values for one cointegrating vector.

Table 4b: Bivariate Johansen Cointegration Trace Statistics, Urea and Factor Prices

	GULF	MC	NPL	GL	WC
	2002-2005				
natgas	4.2890	4.9575	10.2782	7.1798	16.7776*
corn	5.8693	4.9794	6.5874	4.6217	6.9695
	2006-2009				
natgas	17.3635*	19.7293*	18.0725*	19.4210*	17.4187*
corn	21.1532**	23.3610**	31.0466**	22.5552**	30.8602**

*Critical values for one linear cointegrating vector in a bivariate test, significant at 1% is 15.04 and at 5% is 20.04. * implies significance at 5%, ** implies significance at 1%*

Table 4b shows that urea prices and natural gas futures prices were cointegrated during the 2006 to 2009 period, but surprisingly the test results show only WC to be cointegrated in the 2002 to 2005 period. Similar to AA prices, urea prices are only cointegrated with corn futures prices in the 2006 to 2009 period.

2.3.1 AA Prices and Natural Gas Futures Prices

The results from estimating *Equation (2)* of the error correction model (ECM) using AA prices and natural gas futures prices are presented in Table 5 for the 2002 to 2005 period and Table 6 for the 2006 to 2009 period.

Table 5: AA Prices and Natural Gas Futures Prices (2002-2005)

	NOLA	MC	NPL	GL	WC
ppc_natgas	9.780**	8.366**	12.88**	12.08**	8.209**
	(1.791)	(1.381)	(1.715)	(1.667)	(2.155)
ppc_natgas_L1	3.877*	2.570	0.126	-2.163	-0.122
	(1.912)	(1.543)	(1.858)	(1.810)	(2.329)
ppc_natgas_L2		-0.653	-2.633	2.368	-5.069*
		(1.634)	(1.878)	(1.816)	(2.343)
ppc_natgas_L3		0.752	4.941*	1.583	5.022*
		(1.523)	(1.924)	(1.874)	(2.516)
ppc_natgas_L4				-3.316	
				(1.853)	
npc_natgas	-6.312**	-2.568	-3.375	-3.254	-2.761
	(2.379)	(1.825)	(2.281)	(2.194)	(2.849)
npc_natgas_L1	1.202	0.364	-0.998	-1.232	0.155
	(2.235)	(1.863)	(2.291)	(2.253)	(2.853)
npc_natgas_L2	-0.687	3.676*	2.820	0.538	1.253
	(2.199)	(1.757)	(2.214)	(2.179)	(2.750)
npc_natgas_L3	4.993*		-0.359	-0.342	-5.490*
	(2.338)		(2.161)	(2.200)	(2.658)
npc_natgas_L4			5.516**	3.582	
			(2.118)	(2.078)	
ecm_L1	-0.0445**	-0.0458**	-0.0556**	-0.0485**	-0.0355*
	(0.0150)	(0.0135)	(0.0172)	(0.0149)	(0.0152)
Observations	204	204	203	203	204
Adjusted R^2	0.7289	0.8370	0.8278	0.8086	0.7765

Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$

Dummy variables were added to correct for outliers in the residuals. NOLA: 2004w10, 2004w14, 2004w50, 2005w4, 2005w30, 2005w50. MC: 2003w23, 2005w36. NPL: 2003w23. WC: 2003w23, 2005w40. The exchange rate (USD per CAD) was added to the WC regression equation.

Table 5 shows that during the 2002 to 2005 period, the error correction term (*ecm_L1*) was negative and significant as required. The *ecm_L1* coefficients suggest weak adjustment to any disequilibrium in relative prices between AA prices and natural gas futures prices, with the adjustment ranging from 4 % to 6% between locations.

The short run dynamics in Table 5 show that during the 2002 to 2005 period, AA prices adjusted much more rapidly to positive price changes in natural gas futures prices than negative price changes. For NOLA, MC, NPL, GL and WC, positive changes to natural gas prices had an immediate impact on AA prices. However, the results indicate a lagged response in AA prices adjusting to negative natural gas price changes. The results show that MC prices adjusted after two weeks, WC after three weeks and NPL after four weeks. Negative changes to natural gas prices only had an immediate impact on AA prices at the NOLA location. However, the size of the AA NOLA price response in the current period was less following the negative price change compared to the positive price change.

Table 6: AA Prices and Natural Gas Futures Prices (2006-2009)

	NOLA	MC	NPL	GL	WC
ppc_natgas	6.076	-0.358	-1.200	-0.779	10.55
	(9.564)	(5.576)	(5.976)	(5.096)	(19.02)
ppc_natgas_L1	-5.185	-6.088	1.916	5.387	-6.525
	(10.25)	(5.794)	(6.349)	(5.487)	(20.39)
ppc_natgas_L2		0.674			
		(6.035)			
ppc_natgas_L3		9.521			
		(5.685)			
npc_natgas	3.614	-7.702	-3.495	-1.397	-23.99
	(9.758)	(5.283)	(5.823)	(5.049)	(18.59)
npc_natgas_L1	1.699	-6.705	-2.240	-4.131	21.43
	(8.763)	(5.317)	(5.392)	(4.654)	(17.31)
npc_natgas_L2		10.73*			
		(5.206)			
ecm_L1	-0.0318	-0.0194*	-0.0143	-0.0175**	-0.0427*
	(0.0162)	(0.00794)	(0.00730)	(0.00652)	(0.0170)
Observations	206	204	206	206	206
Adjusted R^2	0.3020	0.3289	0.2883	0.2841	0.1214

Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$
Dummy variables were added to correct for outliers in the residuals. NOLA: 2008w30, 2008w48, 2009w8. MC: 2008w27, 2008w47. NPL: 2008w23, 2008w47. GL: 2008w32, 2008w50. The exchange rate (USD per CAD) was added to the WC regression equation.

Table 6 shows that during the 2006 to 2009 period, the error correction term (*ecm_L1*) was negative and significant for all locations, indicating AA prices and natural gas prices were roughly following the same trend. The *ecm_L1* coefficients suggest weak adjustment to any disequilibrium in relative prices between AA prices and natural gas futures prices, with the adjustment ranging from 2 % to 4% between the locations.

However, the short run dynamics changed in the 2006 to 2009 period relative to the 2002 to 2005 period. The results show that during the 2006 to 2009 period, changes in the natural gas futures price, whether positive or negative, did not significantly impact AA prices at any location.

2.3.2 AA Prices and Corn Futures Prices

The results from estimating *Equation (2)* of the ECM using AA prices and corn futures prices are presented in Table 7 for the 2002 to 2005 period and Table 8 for the 2006 to 2009 period.

Table 7: AA Prices and Corn Futures Prices (2002-2005)

	NOLA	MC	NPL	GL	WC
ppc_corn	0.0823	-0.0769	-0.179	-0.0884	-0.133
	(0.182)	(0.120)	(0.140)	(0.124)	(0.222)
ppc_corn_L1	-0.0617	0.00146	0.280*	0.00679	0.271
	(0.198)	(0.131)	(0.130)	(0.118)	(0.203)
ppc_corn_L2	-0.129	0.0576	0.0344	0.0486	
	(0.190)	(0.112)	(0.125)	(0.111)	
ppc_corn_L3			-0.0265		
			(0.123)		
npc_corn	-0.0209	-0.0170	-0.00904	-0.00300	0.0592
	(0.161)	(0.105)	(0.121)	(0.108)	(0.190)
npc_corn_L1	-0.248	-0.0119	-0.192	-0.165	-0.162
	(0.185)	(0.122)	(0.132)	(0.119)	(0.209)
npc_corn_L2	-0.0576	-0.391**			
	(0.179)	(0.114)			
npc_corn_L3	-0.255				
	(0.167)				
npc_corn_L4	-0.0480				
	(0.152)				
ecm_L1	-0.0171	-0.000490	-0.000528	-0.000166	-0.00660
	(0.0112)	(0.00671)	(0.00768)	(0.00682)	(0.0107)
Observations	203	205	204	205	206
Adjusted R^2	0.0142	0.0293	0.0146	0.0263	0.0175

*Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$*

In Table 7, none of the *ecm_L1* terms for the 2002 to 2005 period were significant, revealing that corn futures prices and AA prices were not linked by same trend in the 2002 to 2005 period. This result coincides with the results from the bivariate cointegration tests.

Table 8: AA Prices and Corn Futures Prices (2006-2009)

	NOLA	MC	NPL	GL	WC
ppc_corn	0.607*	0.337**	-0.216	-0.0886	0.101
	(0.244)	(0.123)	(0.138)	(0.217)	(0.422)
ppc_corn_L1	-0.215	-0.186	-0.0691	0.00145	-0.514
	(0.245)	(0.132)	(0.145)	(0.221)	(0.431)
ppc_corn_L2			-0.0900	0.216	
			(0.143)	(0.224)	
ppc_corn_L3			0.212	-0.00261	
			(0.143)	(0.217)	
ppc_corn_L4			0.359*	0.242	
			(0.142)	(0.213)	
npc_corn	0.266	-0.334**	0.382**	0.404*	-0.808*
	(0.210)	(0.104)	(0.123)	(0.189)	(0.366)
npc_corn_L1	0.351	0.0582	-0.313**	-0.0520	0.156
	(0.214)	(0.108)	(0.119)	(0.187)	(0.376)
npc_corn_L2	0.222	0.224*		-0.253	
	(0.215)	(0.111)		(0.191)	
npc_corn_L3	0.0511	0.108			
	(0.216)	(0.109)			
npc_corn_L4	-0.549**				
	(0.200)				
ecm_L1	-0.0454*	-0.0265**	-0.0195*	-0.0498**	-0.0883**
	(0.0187)	(0.00988)	(0.00915)	(0.0141)	(0.0203)
Observations	203	204	203	203	206
Adjusted R^2	0.4114	0.5334	0.5156	0.4998	0.4078

Standard errors in parentheses.* $p < 0.05$, ** $p < 0.01$
Dummy variables were added to correct for outliers in the residuals. NOLA: 2008w30, 2008w48, MC: 2008w27, 2008w47, NPL: 2008w23, 2008w50, WC: 2008w23. The exchange rate (USD per CAD) was added to the WC regression equation

However, Table 8 shows that in the 2006 to 2009 period, the *ecm_L1* coefficients were significant for all price locations, indicating that during the 2006-2009 period, corn futures prices and AA prices followed the same trend. The *ecm_L1* coefficients suggest relatively weak adjustment during the 2006 to 2009 period, with the adjustment ranging from 2% to 9% between locations.

Aside from the NOLA location, AA prices at the MC, NPL, GL and WC locations all adjusted to negative corn futures price changes in the current period. There was no discernable pattern for AA prices adjusting to positive price changes for corn futures, with NOLA and MC showing immediate adjustment, but NPL showing a lag in adjustment of four weeks.

In summary, the empirical results show that during the 2002 to 2005 period, natural gas prices had more of an impact on movements in AA fertilizer prices. However, during the 2006 to 2009 period, corn futures prices had more of an impact on AA fertilizer prices. In the 2002 to 2005 period, AA prices tended to respond rapidly to positive natural gas futures price changes, while the response to declining natural gas futures prices was delayed. In the 2006 to 2009 period, the response of AA prices to negative corn futures price changes was immediate, while the response to positive price changes to corn futures was mixed.

2.3.3 Urea Prices and Natural Gas Futures Prices

The results from estimating *Equation (2)* of the ECM using urea prices and natural gas futures prices are presented in Table 9 for the 2002 to 2005 period and Table 10 for the 2006 to 2009 period.

Table 9: Urea Prices and Natural Gas Futures Prices (2002-2005)

	GULF	MC	NPL	GL	WC
ppc_natgas	1.861*	2.038*	3.101*	6.367**	4.707**
	(0.895)	(0.842)	(1.536)	(0.926)	(1.548)
ppc_natgas _L1	1.907	3.246**	2.852	-0.716	-0.172
	(1.002)	(0.943)	(1.655)	(0.990)	(1.688)
ppc_natgas_L2	-1.207	-1.650			-2.836
	(0.968)	(0.910)			(1.701)
ppc_natgas_L3					5.135**
					(1.747)
npc_natgas	-2.431*	-1.673	-5.644**	-1.919	-1.391
	(1.202)	(1.130)	(2.030)	(1.210)	(2.066)
npc_natgas _L1	1.280	0.219	-0.849	-0.0701	0.704
	(1.152)	(1.084)	(1.925)	(1.132)	(2.047)
npc_natgas _L2			-0.169		1.215
			(1.902)		(1.990)
npc_natgas _L3			5.547**		-4.299*
			(1.953)		(1.927)
ecm_L1	-0.00712	-0.00836	-0.0282	-0.0158	-0.0400*
	(0.00850)	(0.00856)	(0.0154)	(0.00924)	(0.0170)
Observations	205	205	204	206	204
Adjusted R^2	0.6674	0.7420	0.7198	0.7571	0.7549

Standard errors in parentheses. * *$p < 0.05$,* ** *$p < 0.01$*

Table 9 shows that during the 2002 to 2005 period, the error correction term (*ecm_L1*) is only negative and significant for the WC location, confirming the surprising results of the bivariate cointegration tests. The short run results for urea WC during the 2002 to 2005 period indicate a similar pattern to what was observed between AA and natural gas prices over the same period. WC urea prices adjusted rapidly to positive price changes in natural gas futures prices, and there was also a lag in adjustment to declining natural gas prices, with adjustment occurring after three weeks.

Table 10: Urea Prices and Natural Gas Prices (2006-2009)

	GULF	MC	NPL	GL	WC
ppc_natgas	5.001	4.497	1.773	1.170	-3.913
	(5.541)	(4.959)	(5.491)	(5.179)	(10.44)
ppc_natgas_L1	-6.095	-4.798	1.342	1.787	3.235
	(5.749)	(5.292)	(5.897)	(5.534)	(11.20)
ppc_natgas_L2	2.561				
	(5.804)				
ppc_natgas_L3	6.864				
	(5.856)				
npc_natgas	-7.741	-14.79^{**}	2.684	-0.345	8.631
	(5.175)	(4.886)	(5.576)	(5.054)	(10.21)
npc_natgas_L1	-3.252	5.008	-5.757	-4.911	-12.46
	(5.364)	(4.514)	(5.119)	(4.761)	(9.492)
npc_natgas_L2	3.509				
	(5.368)				
npc_natgas_L3	6.670				
	(4.931)				
ecm_L1	-0.0298^{**}	-0.0261^{**}	-0.0277^{**}	-0.0296^{**}	-0.0403^{*}
	(0.0107)	(0.00976)	(0.0104)	(0.00988)	(0.0166)
Observations	204	206	206	206	206
Adjusted R^2	0.3704	0.3304	0.3078	0.3146	0.1344

Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$

Dummy variables were added to correct for outliers in the residuals. GULF: 2008w18, 2008w43. MC: 2008w19, 2008w41. NPL: 2008w28, 2008w42. GL: 2008w19. The exchange rate (USD per CAD) was added to the WC regression equation.

The empirical results in Table 10 show that the error correction term (*ecm_L1*) was negative and significant, for all locations, during the 2006 to 2009 period. Therefore, urea prices and natural gas prices were found to follow roughly the same trend in the 2006 to 2009 period. The *ecm_L1* coefficients suggest weak adjustment in both periods to any disequilibrium in the relative prices of urea and natural gas futures prices, with the adjustment ranging from 3% to 4% between locations.

The short run dynamics between urea prices and natural gas prices during the 2006 to 2009 period suggest that changes in the natural gas prices in the short run, whether positive or negative, had little impact on urea prices. These results coincide with what was observed between AA prices and natural gas futures prices during the 2006 to 2009 period (Table 6).

2.3.4 Urea Prices and Corn Futures Prices

The results from estimating *Equation (2)* in terms of urea and corn futures prices are presented in Table 11 for the 2002 to 2005 period and Table 12 for the 2006 to 2009 period.

Table 11: Urea Prices and Corn Futures Prices (2002-2005)

	GULF	MC	NPL	GL	WC
ppc_corn	0.0588	0.0155	-0.102	-0.0285	-0.00798
	(0.0618)	(0.0605)	(0.111)	(0.0701)	(0.140)
ppc_corn_L1	0.0116	0.0199	0.0293	0.0317	0.00831
	(0.0566)	(0.0554)	(0.102)	(0.0642)	(0.128)
npc_corn	-0.0709	-0.0626	-0.0343	-0.0558	0.00895
	(0.0531)	(0.0519)	(0.0952)	(0.0601)	(0.120)
npc_corn_L1	-0.0675	-0.0719	-0.116	-0.115	-0.0804
	(0.0580)	(0.0568)	(0.104)	(0.0657)	(0.131)
ecm_L1	-0.00595	-0.00313	-0.00807	-0.00221	-0.0100
	(0.00516)	(0.00472)	(0.00847)	(0.00527)	(0.0108)
Observations	206	206	206	206	206
Adjusted R^2	0.0737	0.0684	0.0392	0.0651	0.021

Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$

In Table 11, none of the *ecm_L1* terms for the 2002 to 2005 period are significant, revealing that corn futures prices and urea prices were not linked by the same trend in the 2002 to 2005 period. This coincides with the results from the bivariate cointegration tests and matches the results for AA in Table 7.

However, Table 12 shows that in the 2006 to 2009, the *ecm_L1* term was significant for all price locations, indicating that during the 2006 to 2009 period, corn futures prices and urea prices were linked. The *ecm_L1* coefficients suggest weak adjustment in the 2006 to 2009 period, with the adjustment ranging from 3 to 6%.

The short run response of urea prices to changes in corn futures prices indicates that there was generally a lag in urea prices adjusting to crop futures price increases, while there was a more immediate response from urea prices to declining crop futures prices. For instance, urea prices at the GULF, MC, NPL and GL locations all responded to rising corn futures prices after three weeks. However, at the MC, NPL, GL and WC locations, negative corn futures price changes were reflected in the urea price in the current period or within one week.

Table 12: Urea Prices and Corn Futures Prices (2006-2009)

	GULF	MC	NPL	GL	WC
ppc_corn	0.155	-0.0762	-0.222	0.00720	0.00201
	(0.157)	(0.128)	(0.157)	(0.128)	(0.114)
ppc_corn_L1	0.217	0.0327	-0.0465	0.0507	-0.0498
	(0.163)	(0.138)	(0.166)	(0.138)	(0.117)
ppc_corn_L2	-0.0385	0.0917	0.265	0.133	
	(0.164)	(0.136)	(0.164)	(0.136)	
ppc_corn_L3	0.327*	0.451**	0.331*	0.259*	
	(0.150)	(0.128)	(0.163)	(0.128)	
ppc_corn_L4			0.249		
			(0.160)		
npc_corn	-0.00868	0.316**	0.305*	0.257*	-0.179
	(0.134)	(0.111)	(0.139)	(0.111)	(0.0999)
npc_corn_L1	0.0806	0.224*	0.222	0.178	-0.203*
	(0.137)	(0.113)	(0.137)	(0.114)	(0.102)
npc_corn_L2	0.613**				
	(0.139)				
ecm_L1	-0.0447*	-0.0449**	-0.0581**	-0.0516**	-0.0293**
	(0.0191)	(0.0158)	(0.0193)	(0.0155)	(0.0108)
Observations	204	204	203	204	206
Adjusted R^2	0.6778	0.6690	0.6841	0.6612	0.4770

Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$.
Dummy variables were added to correct for outliers in the residuals WC: 2008w22, 2008w49. The exchange rate (USD per CAD) was added to the WC regression equation.

In summary, the results indicate that natural gas prices had more of an influence on urea prices in the 2002 to 2005 period, while corn futures prices had more of an impact on urea prices in the 2006 to 2009 period. In the 2002 to 2005 period, the WC urea price responded rapidly to positive natural gas price changes, while the response to declining natural gas prices was delayed. In contrast, urea prices in the 2006 to 2009 period responded more rapidly to declining corn futures prices compared to price increases.

3. Conclusion

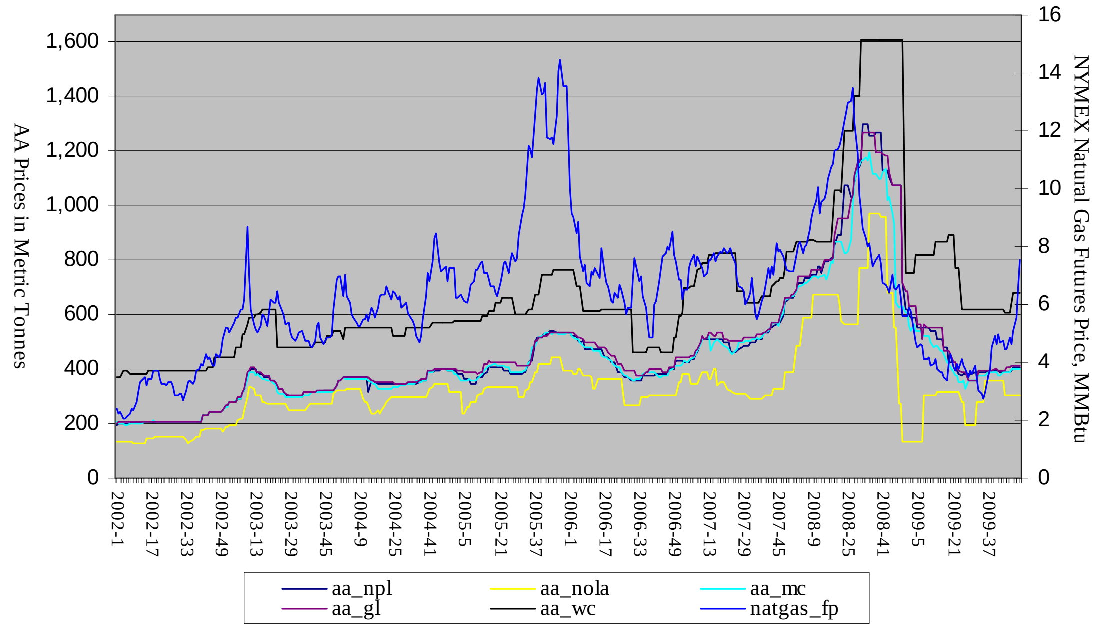
The empirical results indicate that both the relative importance of factor prices and the nitrogen price adjustment process, changed between the 2002 to 2005 and 2006 to 2009 periods. During the 2002 to 2005 period, natural gas futures prices had more of an impact on nitrogen prices, particularly AA prices. Figures 1 and 2 show that in the 2002 to 2005 period, natural gas prices were more volatile than corn futures prices, and also trended more closely with AA prices.

In addition, during the 2002 to 2005 period, nitrogen prices tended to respond to positive price changes in natural gas prices in a shorter period of time relative to negative changes. This result reflects the attempt by fertilizer producers to minimize costs by immediately adjusting output prices to reflect the higher variable costs incurred for producing the same level of output. Furthermore, the delayed price response to declining variable costs reflects an attempt to maximize margins by delaying the transmission of lower variable costs through to lower output prices.

In contrast to the 2002 to 2005 period, corn futures prices had a significant impact on nitrogen price movements in the 2006 to 2009 period. Figures 1, 2, 3 and 4 illustrate that during the 2006 to 2009 period, corn futures prices were relatively more volatile than natural gas futures prices. Nitrogen prices, particularly urea prices, also trended more closely with corn futures prices over the 2006 to 2009 period. It should also be pointed out that during the 2007 to 2008 period when nitrogen and corn futures prices were at record levels, natural gas futures prices were also well above average. However, the impact of rising variable costs on producer margins was mitigated by the unprecedented level of nitrogen prices.

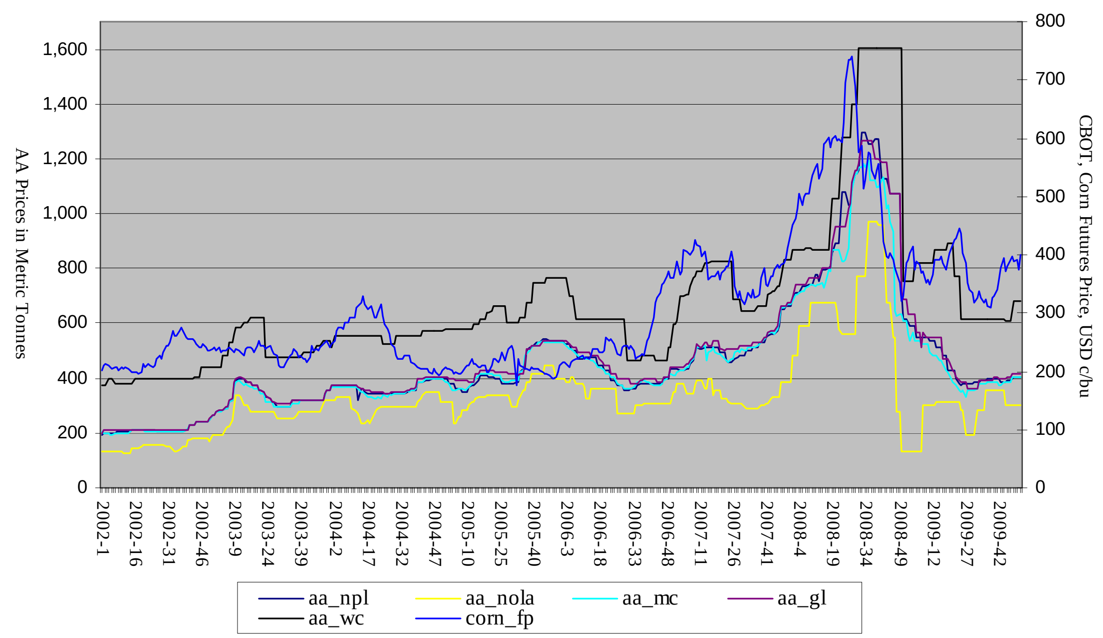
Nitrogen prices also adjusted rapidly to falling futures prices for corn during the 2006 to 2009 period, while nitrogen price adjustments to rising futures prices for corn were mixed. The rapid price adjustment to falling corn futures prices reflects the substantial contraction in fertilizer demand that followed the decline in corn futures prices, beginning in the latter half of 2008. Nitrogen producers were forced to lower prices rapidly and substantially in an attempt to stimulate demand. This was particularly the case for AA producers, given their relatively higher cost of inventory storage.

Figure 1: Weekly AA and Natural Gas Futures Prices 2002-2009



Note: AA-WC price is in CAD, all other AA prices are in USD

Figure 2: Weekly AA and Corn Futures Prices 2002-2009



Note: AA-WC price is in CAD, all other AA prices are in USD

Figure 3: Weekly Urea and Natural Gas Futures Prices 2002-2009

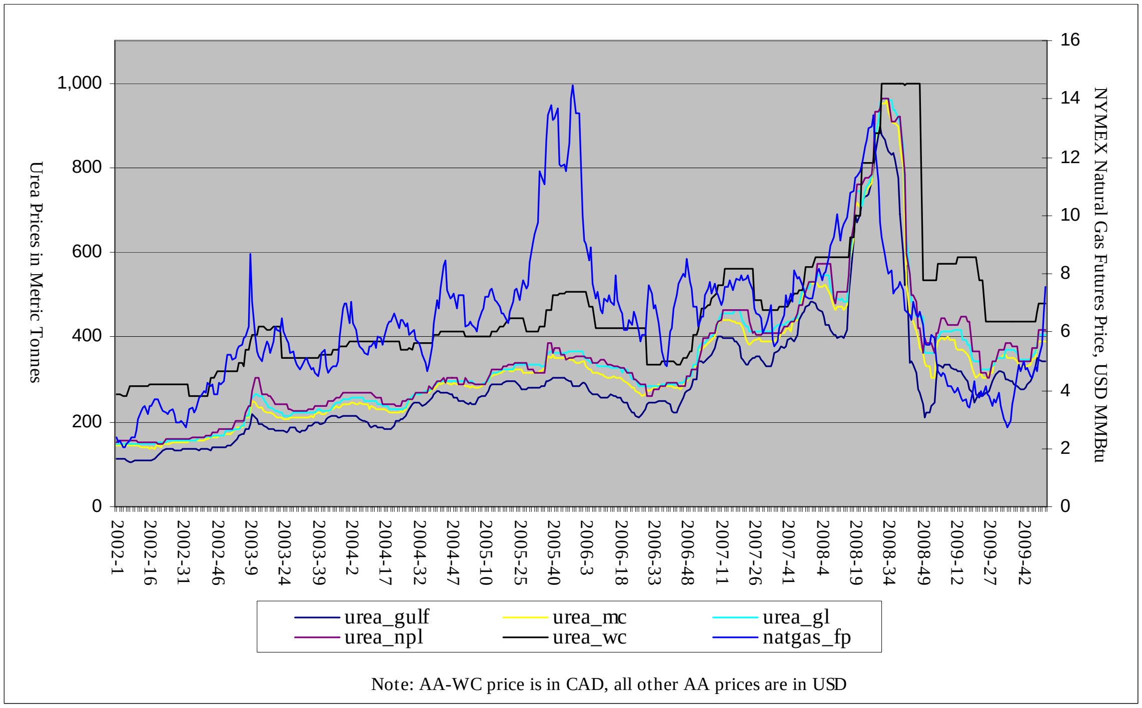
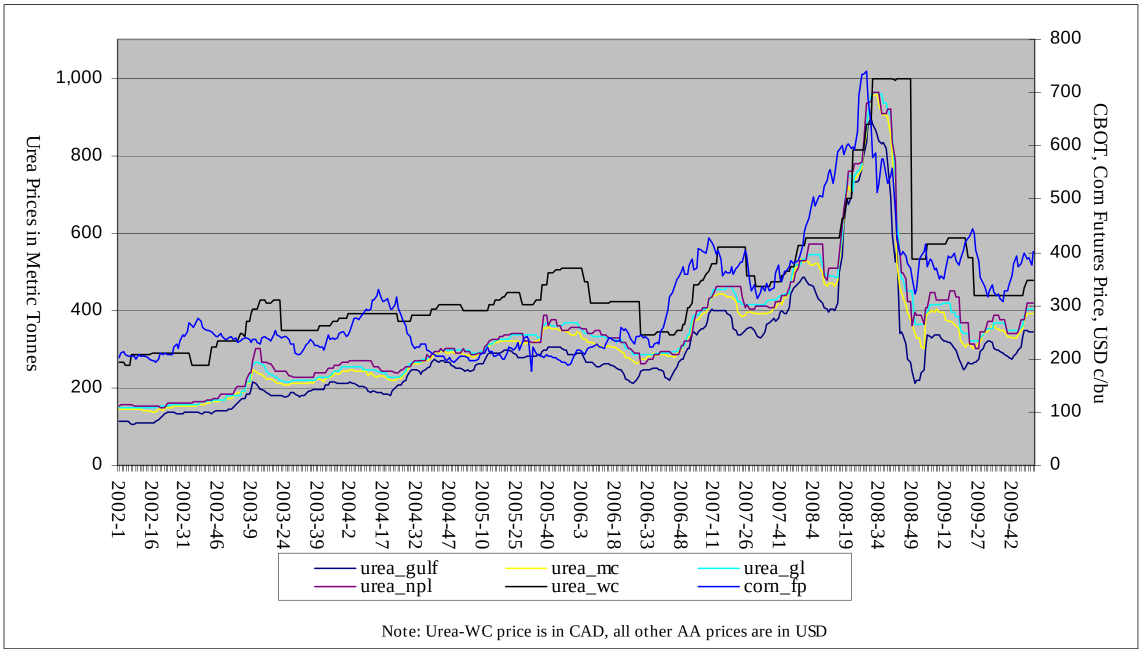


Figure 4: Weekly Urea and Corn Futures Prices 2002-2009



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