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Ethanol Pricing: Explanations and Interrelationships

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Abstract

With the 2005 Energy Bill's passage, the production and use of ethanol is set to become an integral component of the transportation fuel market. Undoubtedly, this will affect the transportation fuel and agricultural industries. This paper uses an econometric time series approach to reveal historical ethanol price behavior and relationships.

Additional Key Words: Ethanol pricing, cointegration

JEL Codes: C32, Q42

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Introduction

The popularity of ethanol as a near-term alternative to petroleum has rapidly expanded over the past five years. This transition to ethanol has been aided by increased gasoline prices and by the 2005 Energy Policy Act (Energy Bill), which mandated 7.5 billion gallons of renewable fuel use by 2012. Ethanol production in the United States has increased from 1.47 billion gallons per year (bgy) in 1999 to 3.4 bgy in 2004, using more than 1.22 million bushels of grain. US ethanol production is being called “the fastest growing energy source in the world” (Kansas Ethanol). This statement is no surprise, with more than 92 ethanol plants in operation in 20 different states, more than 20 plants under construction, and the recent backing ethanol has received with the passage of the Energy Bill.

The domestic demand for ethanol comes from two primary uses in the US fuel market—as an oxygenate and as an alternative fuel source. Oxygenates extend gasoline volumes and allow gasoline to burn cleaner. Today, ethanol and methyl tertiary butyl ether (MTBE) are the primary fuel oxygenates used, however, as of July 2005, 17 states have banned the use of MTBE due to ground water contamination problems, leading to increased demand for ethanol as a fuel oxygenate. Ethanol can also be used as a primary fuel in fuel blends such as E85, consisting of 85% ethanol and 15% gasoline. Ethanol, as an alternative fuel to gasoline, is said to reduce hydrocarbon, benzene, and CO₂ emissions, which are all contributors to pollution and global warming (NEVC 2005). These two uses allow ethanol to be categorized as both a complement to and a substitute for gasoline.

The USDA estimated that 12% of the nation’s 2002/2003 corn crop went toward the production of ethanol (Baker, Allen, and Chambers 2003). As the mandated quantities (set forth by the Energy Bill) of ethanol and renewable fuels come into effect, ethanol production

has the capacity to use an increasing proportion of the nation's corn crop. Kapell (2005) estimated ethanol's share of the US corn crop up to 25% by 2014.

The ethanol industry has changed. No longer is ethanol a remote alternative, but it has and will continue to enjoy mainstream use. These changes in the character of the ethanol industry and the improvements in ethanol production technology have made much of the scholarly research on ethanol production irrelevant to today's industry. Increased demand and production of ethanol are expected to have a significant affect on the pricing of ethanol. Ethanol is currently priced below gasoline, but now that ethanol's demand has been, essentially, mandated by the 2005 Energy Bill, what will happen to prices? A thorough understanding of the historic interrelationships among ethanol and related prices is needed in order to accurately assess and predict the impact of this new Energy Bill.

Methodology

This study uses time series techniques to further our understanding of price dynamics in this rapidly growing industry. The primary intention of this paper is to modernize existing literature on the time series properties of ethanol pricing in an effort to reflect the recent, dramatic changes to the ethanol industry. This investigation will utilize the Johansen and Jesulius multivariate cointegration methodology to search for structural long-run relationships between ethanol and related price series, as well as examine their short-run dynamics.

Fairly modern developments in time series econometrics have empowered researchers with the ability to explore non-stationary time series variables with respect to their relationships with other, "integrated", economic variables (Bhattacharya 2005). Cointegration between multiple non-stationary variables occurs when the linear combination of the variables results in a stationary series (Engle and Granger 1987). Traditionally, the Engle and Granger

(1987) two-step method has been the approach used to test for cointegration, but this method suffers some shortfalls. If a cointegrating relationship is determined, the Engle and Granger methodology assumes it is a unique cointegrating vector (Menon 1993), therefore eliminating the possibility that there are multiple cointegrating vectors. The second main weakness of the Engle and Granger approach is that it fails to allow inferences on the parameters. The Johansen and Juselius (1990) method overcomes these two obstacles and thus is the preferred methodology for this research.

We employed a vector error correction model of the form:

$$(1) \Delta Y_t = \Gamma_0 + \Gamma_1 \Delta Y_{t-1} + \dots + \Pi y_{t-k} + \varepsilon_t$$

The term Π corresponds to the cointegrating relationship between variables. A cointegrating relationship between variables exists if Π is of reduced rank (Π of full rank implies all the endogenous series are stationary and Π of rank 0 indicates that there are no cointegrating vectors). If Π is of reduced rank, then Π can be broken down as $\Pi = \alpha \beta'$. The elements of alpha reveal the speed at which the system responds to a given change in equilibrium (Johansen and Juselius 1990, 1992). In other words, alpha corresponds to the short run adjustments to prices, given a departure from long run equilibrium (Frankel and Schmukler 1996). According to Smith and Harrison (1995) this term can also be described as the strength of attraction or the “attentiveness” to which one series follows the other. Beta embodies the long run structural relationships between variables (Johansen and Juselius 1990).

The Johansen (1988) and Juselius (1992) methodology begins with a unit root test to ensure that all the variables have the same order of integration. The number of cointegrating vectors is determined by doing trace and maximum eigenvalue tests. The cointegrating vectors uncovered in this study describe the relationships between ethanol and the related prices. These processes will be done using the CATS package for the RATS software.

By using the Johansen (1988) and Jesulius (1992) cointegration methodology, ethanol firms can then have a better understanding of how energy prices are intertwined. This understanding will help energy firms and interested parties make informed decisions that incorporate the volatility and dynamics of the ethanol fuel market.

Preliminary Data Analysis

Coltrain (2001) states that ethanol price is the single most important factor in determining the profitability of an ethanol production facility. The vast investment into this industry and the current increases in demand for fuel oxygenates has provoked recent research in the area of forecasting and understanding fuel additive pricing. Coltrain (2001) found that ethanol price follows the “price swings of wholesale unleaded gasoline”, stating that ethanol price is typically 50 cents above the price of wholesale gasoline. Studies by the Clean Fuels Development Coalition (2002) and Gallagher et al. (2003) support this finding, attributing the difference in ethanol and wholesale gasoline price to the federal excise tax. Additionally, Lau et al. (2004) found wholesale gasoline price and federal subsidy level as having a significant affect on ethanol price and used those prices to make cointegrated short term density forecasts on ethanol prices.

However, since those studies occurred, ethanol and gasoline prices have not followed the consistent historical pattern (see figure 1). Around March of 2005, ethanol price began to drop below average US wholesale gasoline price. Hart (2005) attributes this divergence to the expansion of ethanol production and the expansion of ethanol products that serve as a competitor to gasoline, such as E85. Ethanol has since recovered its 50 cent margin over gasoline as of October 2005. This “switch” in prices presents the opportunity to investigate how prior research showing that ethanol tracks wholesale gas prices may no longer be

appropriate. Analysis will help determine if the switch was simply an anomaly or actual change in price behavior.

Research by Otto and Gallagher (2001) and Kapell (2003) suggest drivers such as corn price, natural gas price, and oil price may be motivating ethanol prices. Our research began with an understanding of the relationships between ethanol and the other variables thought to describe the movements in ethanol prices. Figure 2 illustrates these production and consumption relationships. Consumption relationships are indicated as either a substitution or complementary relationship, therefore indicating the directional relationship we would expect.

Ethanol is closely related to corn and natural gas in the production process as both are primary production inputs. Natural gas is also used in the production of MTBE. Crude oil is obviously tied to the production of gasoline, which in turn is related to MTBE and Ethanol on the consumption end. MTBE, serving as a fuel oxygenate, is a complement to gasoline and would thus be expected to have a positive relationship in price. The banning of MTBE in several states makes ethanol and MTBE no longer direct substitutes for one another; however, we would still typically expect a negative price relationship. As discussed earlier, ethanol can be used either as a substitute or as a complement to MTBE, thus making ethanol's price relationship with gasoline indefinite. However, since the use of ethanol as an oxygenate is currently predominate, one may hypothesize that there is a positive relationship between the two.

The data used in this research consist of US average prices reported monthly. The time series that we used began June of 1989 and ended August of 2005 for a total of 194 data points. Ethanol prices and MTBE prices were obtained from Hart's *Oxy Fuel News*, a fuel industry reporting service. Natural gas, crude oil, and gasoline prices were obtained from the Energy Information Agency. Corn prices were obtained from the National Agricultural

Statistics Service (NASS). For the purposes of this research ethanol price will be represented by *ETHP*, natural gas price by *NGP*, corn price by *CP*, gasoline price by *GP*, crude oil price by *COP*, and MTBE price by *MTBEP*.

Initial relationships between the variables were analyzed using a correlation matrix. The correlation between ethanol prices and these variables are relatively high (Table 1). Somewhat surprisingly, given the input cost requirements for the production of ethanol, the only variable that had little correlation to ethanol price was corn price. However, there is literature available that suggests corn price has little affect on ethanol price (Lau et al.2004).

Analysis

Since we are looking for cointegrating relationships, we are interested in finding variables that are non-stationary in levels and stationary in first differences (Granger 1981). Failure to recognize non-stationarity could result in spurious regressions. Spurious regressions are illusory significant long-run relationship caused by “contemporaneous correlations” as compared to the “meaningful causal relationships” that we are searching for (Harris 1995).

The widespread test for stationarity is an augmented Dickey-Fuller (ADF) test which incorporates lagged values. The ADF tests the null hypothesis that the series is non-stationary against the alternative hypothesis that the series is stationary. We used a 5% critical value for this research and would reject the null hypothesis (i.e. the series is stationary) if the ADF test returned a t-value less than -2.90. The results showed that all variables except corn price are non-stationary. By taking the first difference of each variable, each series can be made stationary. Table 1 reports the results of the augmented Dickey-Fuller test from the RATS output with significant results in bold. The lags reported for each variable are the optimal number of lags selected by the Bayesian Information Criterion.

Given the majority of our variables are non-stationary, cointegration analysis can be applied to determine if long run relationships exist. Before going any further we needed to determine the number of cointegrating vectors in the system. Johansen proposed two likelihood ratio tests for determining the number of cointegrating vectors, the lambda max test and the trace test. Both tests use eigenvalues to compute associated test statistics. The literature suggests that neither test dominates in all areas (Paruolo 2001). In this study, both tests revealed the same answer shown in Table 1, that there are 4 cointegrating vectors in this system.

Upon determining that there are 4 cointegrating vectors in this system, it was necessary to determine how many lags the system requires. CATS was used to compare residual analysis results using different lag lengths. Both the Schwartz Information Criteria (SIC) and Hannan-Quinn (HQ) indicated that 2 lags were appropriate for this model, given 4 cointegrating vectors.

Having discovered that there are multiple cointegrating relationships in the system, restrictions were placed on alpha and beta to determine the nature of the relationships, initially dealing with the restrictions on the betavectors. Each betavector corresponded to one cointegrating relationship. Since corn price is stationary to begin with, a linear combination of variables is not needed to make it stationary. We therefore initially test a single restriction on the cointegration space that one vector contains only corn prices. We reject this hypothesis using a likelihood ratio test with a p-value of 0.00 ($\chi^2(2)=17.49$). This leads us to suspect that a type 1 error occurred during the ADF tests and corn prices were in fact non-stationary and therefore did not need to be treated as its own cointegrating vector. Ultimately, a set of four unique cointegrating vectors was identified. The first cointegrating relationship included gasoline price and crude oil price. The second relationship included ethanol price, natural gas

price and MTBE price. Natural gas price and corn price were included in the third relationship, while the fourth and final relationship was made up by ethanol price and gasoline price. The p-value for this combination was .37, which indicated that we would fail to reject the null hypothesis that the remaining elements of β are zero.

The next step was to test for variables that might be weakly exogenous to the system. A weakly exogenous series does not respond to a deviation in the long run relationship. No variables were of particular suspect for weak exogeneity; however, the test was done for thoroughness. When tests were done on the alpha restrictions for each of the six variables, given the restrictions that were found on the betavectors, the returned p-values were less than .02, indicating that none of the 6 variables were weakly exogenous to the system.

Results and Discussion

The results of this analysis were in two parts; alpha, the speed of adjustment towards equilibrium, and beta, the structural long run relationships between the variables. The results for our analysis are reported in Table 2. The results were normalized to the variable we thought to be dependent in each cointegrating relationship.

The first cointegrating relationship between gasoline and crude oil prices was expected due to the obvious close relationship. Going back to the correlation matrix in Table 1, gasoline price and crude oil price have a correlation coefficient of .97. The relationship is of the proper direction and the magnitude is likely to be based on costs of refinement and differences in the units the prices reported; clearly this relationship is justified.

Perhaps the most complex pricing relationship we found in our results was the second cointegrating relationship involving ethanol, natural gas, and MTBE prices. This cointegrating

relationship can be interpreted as ethanol price being determined by the following equation, where γ is a constant value:

$$(2) \text{ EHP} = \gamma + .062 \text{ NGP} + .366 \text{ MTBEP}$$

The signs on this equation match our expectations, given the individual relationships between natural gas and MTBE with ethanol. Natural gas is one of the primary inputs into the production of both ethanol and MTBE. Therefore, we would expect natural gas prices to be positively related to ethanol prices; as the cost of natural gas increases so does the cost of producing ethanol. Clearly, costs alone do not dictate prices; however, we tend to expect some depressed supply within the ethanol industry in response to increases in the costs of production causing an increase in ethanol price.

Ethanol and MTBE have a long history of being substitutes for one another, both serving as the primary oxygenates in transportation fuel to boost octane levels and meet clean air requirements. There are several current events that may have changed and will continue to affect the relationship between ethanol and MTBE. These events should be thoroughly considered when making an economic interpretation of the relationship described by the cointegrating equation. As a result of states' banning MTBE use, we expect the use of ethanol to expand to meet the demand that MTBE can no longer fill. However, the 2005 Energy Bill has eliminated the two percent oxygenate requirement. Oxygenates may still be needed in gasoline blends to meet clean air standards, but are no longer required by law. Nevertheless, over the time series we analyzed the substitution relationship between ethanol and MTBE holds. As indicated by formula (2), if MTBE prices rise we would expect an increased demand for its substitutes, ethanol being the predominate substitute. This increased demand for ethanol will result in increased ethanol price. The coefficient of .366 most likely depicts the fact that MTBE is not a direct substitute for ethanol in many locations.

The third cointegrating relationship interconnects ethanol price and corn price. This cointegrating relationship can be written as:

$$(3) \text{ EHP} = \gamma + 1.01 \text{ CP}$$

Again, γ can be interpreted as a constant in the equation. These results indicate a nearly one-to-one relationship between corn and ethanol prices. Corn is a major input into the production of ethanol, Urbanchuk (2002) estimates corn accounts for 71% of an ethanol plants operating costs, yet the relative magnitudes of the coefficients in this vector are somewhat unexpected given typical conversion ratios. This relationship between ethanol prices and corn prices would have been overlooked had simple correlation been the only method used to compare the two series. This long-run stable relationship between corn and ethanol prices has been suspected for sometime, yet this is the first econometric study done to show the relationship.

The final cointegrating relationship relates ethanol prices to gasoline prices. Unlike the interrelationship between corn and ethanol, the relationship between ethanol and gasoline has been shown before and is of no surprise. Based upon these results ethanol price can be written as follows:

$$(4) \text{ EHP} = \gamma + .008 \text{ GP}$$

As discussed earlier in this paper, ethanol serves as both a substitute to and a complement for gasoline. Based upon the relationship described by this cointegrating vector, we can assert that ethanol's role as a substitute to gasoline has been dominant. As a substitute, theoretically, if the price of gasoline rises, demand for gasoline will decline, resulting in increased demand for gasoline substitutes and increased prices of the substitutes. However, from the magnitude of the coefficient we can interpret there to be a very weak substitution effect. The weakness in this substitute relationship is likely caused by the competing complementary relationship. If

the use of alternative ethanol based fuels continues, we would expect the substitution relationship to increase.

The second part of valuable information gained from these results comes from the interpretation of ethanol's role in the alpha matrix (presented in Table 2). The alpha matrix displays the speeds of adjustment to deviations from the long run equilibrium, an element of the short run adjustments. Alpha is organized into a 6 by 4 matrix, each row corresponding to a variable and the columns corresponding to a cointegrating equation (labeled alpha1 through alpha4). Therefore, the row of particular concern and the focus for this discussion is the first row, ethanol's speeds of adjustment. The t-values for the alpha matrix are also presented in Table 2. At a 95% confidence level, these two tailed t-test values become significant if they are larger, in absolute value, than 1.96. Based on this, there is only one significant speed of adjustment associated with ethanol, the alpha3 value of .03. This value is associated with the third cointegrating relationship between corn prices and ethanol prices and indicates a move toward equilibrium upon a shock to the system. Relative to ethanol prices, corn will move back to equilibrium about 1.933 ($.058/.03$) times faster, indicating a short run sensitivity to corn prices.

Future Research and Conclusions

Estimation of the long run structural relationships of a system of variables is only an initial step to understanding the complete model (Harris 1995). The short run behavior of the system must also be estimated. Additionally, short run ethanol price forecasts can be made to get a better idea of what to expect as ethanol's future comes forth.

Through the work done in this paper we have successfully been able to show a linkage between ethanol prices and corn prices, confirm historical linkages between ethanol and

gasoline prices, and show a relationship between MTBE, natural gas, and ethanol prices. This information should prove useful for decision makers involved in the ethanol industry and those concerned with the future of ethanol pricing.

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Figure 1: Monthly Ethanol and Wholesale Gasoline Prices (US averages)

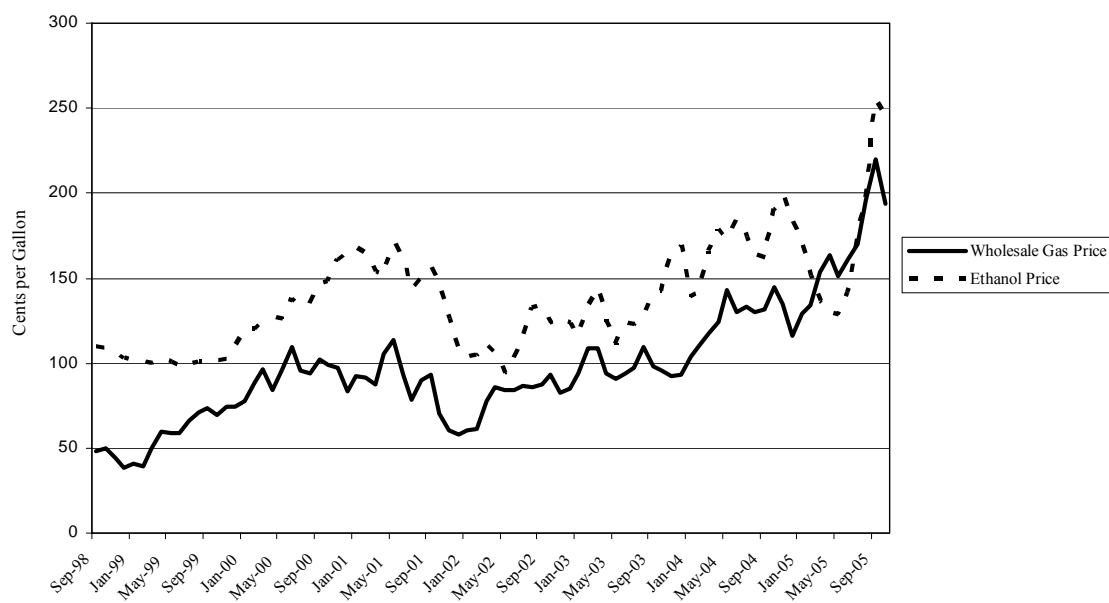


Figure 2: Relationships between Variables of Interest

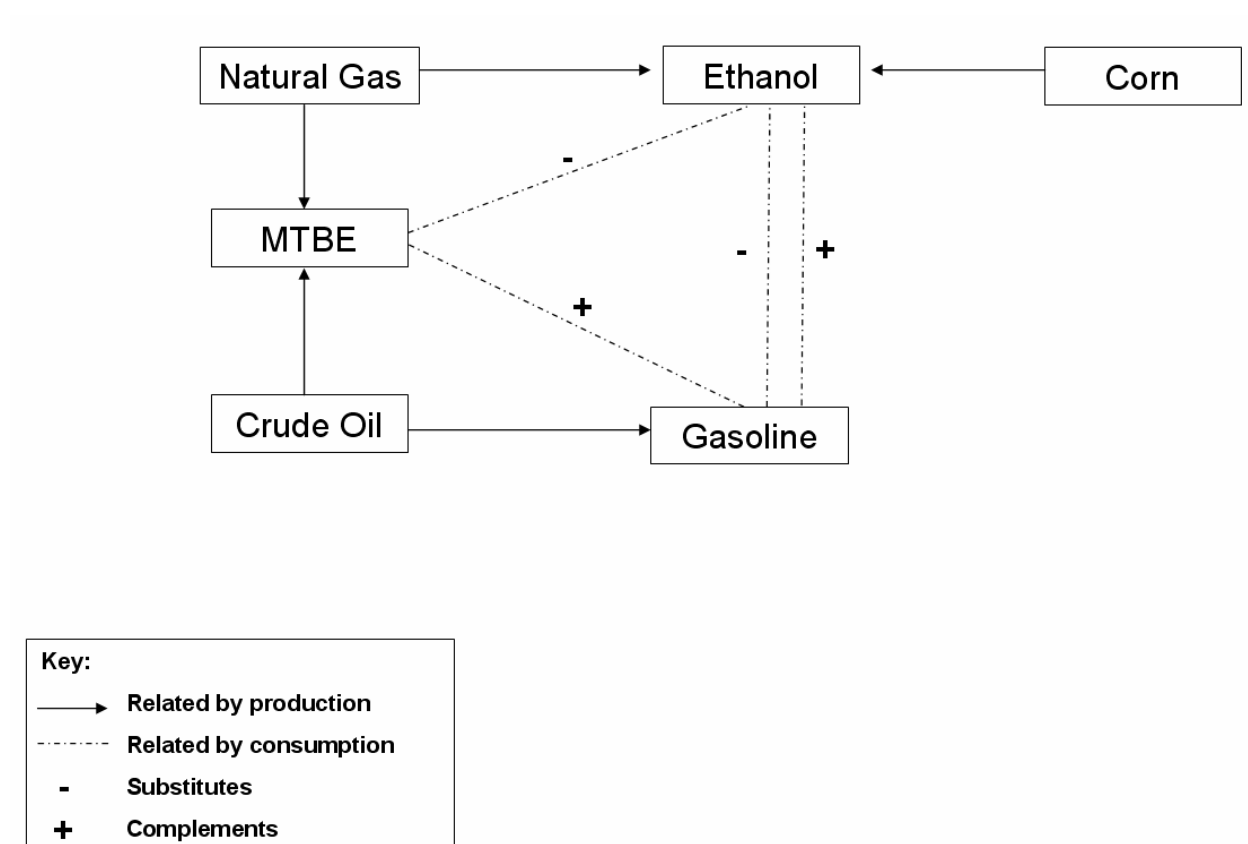
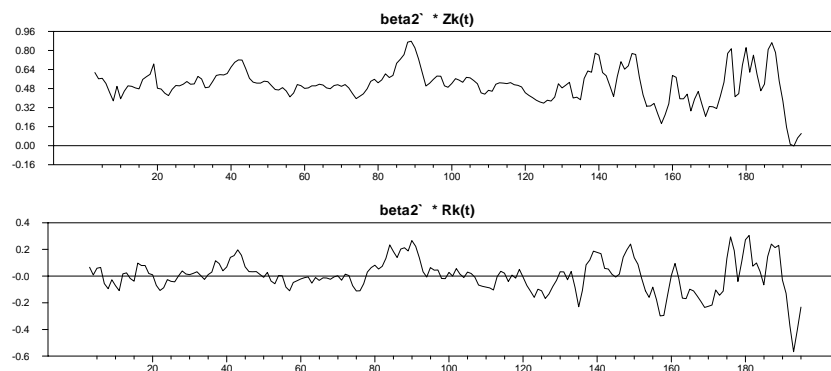
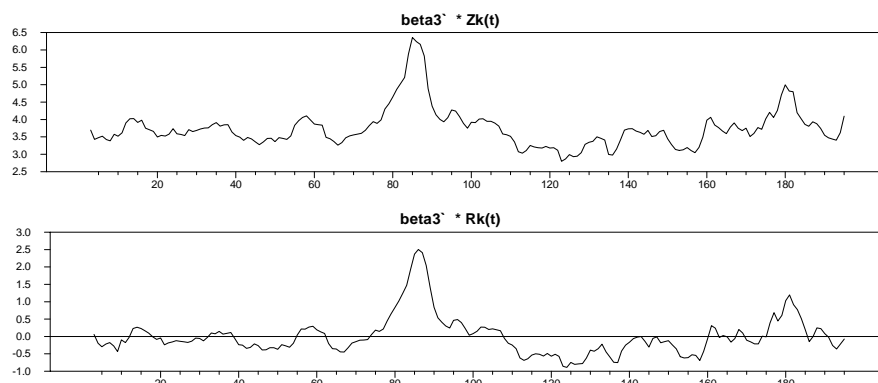


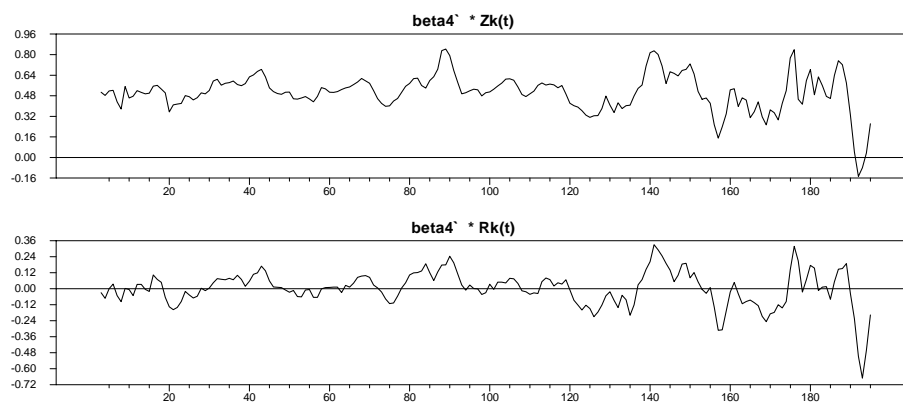
Figure 3: Cointegrating Relationships



Cointegrating relationship 2: Ethanol, natural gas, and MTBE Prices



Cointegrating relationship 3: Ethanol price and corn price



Cointegrating relationship 4: Ethanol price and gasoline price

Table 1: Preliminary Results

Correlation Matrix

	ETHP	NGP	CP	GP	COP	MTBEP
ETHP	1	0.74	-0.03	0.77	0.75	0.68
NGP		1	-0.23	0.87	0.84	0.70
CP			1	-0.18	-0.21	-0.20
GP				1	0.97	0.89
COP					1	0.87
MTBEP						1

Augmented Dicky Fuller Results*

Variable	Original		1 Difference	
	T-stat	Lags	T-stat	Lags
Ethanol Price	-2.9070	2	-10.977	1
Natural Gas Price	-1.5002	1	-11.425	0
Corn Price	-3.9263	1	-7.763	0
Gas Price	0.1874	2	-11.203	1
Crude Oil Price	-0.9368	1	-9.762	0
MTBE Price	0.3946	2	-10.461	1

*All values include a trend

*Significant values are in bold

I(1) ANALYSIS

Eigenvalue	L-max	Trace	HO: r	p-r	L-max90	Trace90
0.4209	105.43	215.26	0	6	24.63	89.37
0.2159	46.94	109.83	1	5	20.90	64.74
0.1757	37.30	62.89	2	4	17.14	43.84
0.0699	13.98	25.58	3	3	13.39	26.70
0.0444	8.77	11.60	4	2	10.60	13.31
0.0146	2.83	2.83	5	1	2.71	2.71

Table 2: RATS Results

BETA (transposed)

ETHP	NGP	CP	GP	COP	MTBEP
0.000	0.000	0.000	1.000	-3.062	0.000
1.000	-0.062	0.000	0.000	0.000	-0.366
1.000	0.000	-1.010	0.000	0.000	0.000
1.000	0.000	0.000	-0.008	0.000	0.000

ALPHA

T-VALUES FOR PI

	Alpha1	Alpha2	Alpha3	Alpha4					
DETHP	0.000	-0.190	0.030	-0.105		-0.213	-1.947	2.817	-1.179
DNGP	-0.013	1.042	-0.023	-0.955		-0.384	3.179	-0.639	-3.194
DCP	-0.003	-0.093	-0.058	0.090		-1.816	-0.533	-3.067	0.566
DGP	-0.346	-27.945	1.796	19.835		-5.400	-4.370	2.595	3.399
DCOP	0.034	-6.814	0.569	2.693		1.468	-2.994	2.311	1.296
DMTBEP	-0.004	0.069	0.025	-0.262		-2.224	0.429	1.439	-1.776

PI

	ETHP	NGP	CP	GP	COP	MTBEP
DENTHP	-0.266	0.012	0.030	0.001	0.001	0.070
DNGP	0.064	-0.064	-0.023	-0.005	0.039	-0.381
DCP	-0.061	0.006	-0.059	-0.004	0.010	0.034
DGP	-6.314	1.729	1.814	-0.506	1.060	110.224
DCOP	-3.553	0.422	0.575	0.012	-0.103	2.493
DMTBEP	-0.166	-0.004	0.025	-0.001	0.011	-0.025

T-VALUES FOR PI

	ETHP	NGP	CP	GP	COP	MTBEP
DENTHP	-6.334	1.947	2.817	0.496	0.213	1.947
DNGP	0.456	-3.179	-0.639	-1.150	3.840	-3.179
DCP	-0.812	0.533	-3.067	-1.703	1.816	0.533
DGP	-2.302	4.370	2.595	-6.022	5.400	4.370
DCOP	-3.637	2.994	2.311	0.398	-1.468	2.994
DMTBEP	-2.416	-0.429	1.439	-0.710	2.224	-0.429