Gasoline and Crude Oil: Evidence of Asymmetric Price Changes during 2008?

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I. Introduction

Markets in the U.S. were hammered in 2008 by the storm of recession and they were buffeted by the winds of uncertainty. Unknown to most, the year began in recession. By the end of the year, real GDP had fallen at an annual rate of 6.3 percent and the unemployment rate increased from 4.9 percent in January to 7.2 percent in December. The bear market gained steam as the Dow Jones Industrials fell from 10,365.45 to 8,776.389 at the end of the year, a decline of more than 15 percent. But it was the volatility in crude oil and gasoline markets that first caught both the attention and angst of consumers and the media.

Fueled by increased demand from the growing economies of India and China and the political uncertainty of the Middle East, crude oil prices rose from $95.95 a barrel in January to $145.31 a barrel just before the Fourth of July: an increase of almost 52 percent. Given the increase in the price of crude oil, an input in production, the price of unleaded regular gasoline increased from $3.04 a gallon on January 1st to $4.11 a gallon on July 10th, an increase of more than 35 percent. Then the global recession took hold and the prices reversed. From July 4th to December 23rd, the price of crude fell more than 79 percent from $145.31 to $30.28. Likewise, the price of regular gasoline also fell from its peak of $4.11 a gallon to $1.60 a gallon on December 28th, a decline of more than 61%.

Sudden and significant increases in the cost of gasoline at the pump will bring cries of price gouging and a period of a falling gasoline prices will bring complaints of asymmetric changes in the price of gasoline. Coined the "rockets and feathers" hypothesis, the argument is that an increase in the price of crude will cause the price of gasoline at the pump to rocket upwards, but as the price of crude falls, the price of gasoline responds like a falling feather, slowly floating downwards.[1] This hypothesis has been studied in the past, using different frequency of data and a variety of modeling techniques, sometimes resulting in conflicting findings. Using semimonthly data between March 1986 and December 1992, Borenstien, Cameron and Gilbert (1997) confirm the presence of an asymmetric price response: gas prices increase faster with rising crude prices and fall slower with decreases in the price of crude. However, Bachmeier and Griffin (2003) use daily data between 1985 and 1998 and find no evidence of the "rockets and feathers" behavior.

This paper tests for the asymmetric price behavior using daily 2008 data. This time period is particularly interesting because of the great volatility in crude oil and gasoline prices. The first half of the year was marked by a sustained, significant increase in prices, while the last half of the year saw a dramatic plunge in prices. Two different statistical models are tested. One set of regressions corrects for serial correlation while another set of regressions use ordinary least squares and tests whether crude and gasoline prices are cointegrated using the estimation techniques made popular by Engle and Granger (1987).

Setting the sample equal to the entire year, we find no evidence of asymmetric price behavior using either estimation technique. However, Chow tests indicate the parameters of the models may be unstable over the entire sample. The data is partitioned into the first part of the year when crude prices were generally rising and the second part of the year after crude prices had hit their peak and the price of crude was falling precipitously. In the first part of the year when prices were generally rising, statistical tests indicate the presence of asymmetries in the behavior of gasoline prices. When crude oil prices were rising in general, the "rocket and feather" behavior occurs. However, there is no statistical evidence of price asymmetries when crude oil prices were on a downward trend during the second half of the year.

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[1] See Bacon (1991).

In analyzing the behavior between gasoline and crude prices, the paper has the following organization. A brief review of the relevant literature follows this introduction. The merits of two different estimation techniques are discussed and the models are specified. After describing the methodology, a section describing the data and the results of unit root test and Granger causality tests follows. The regression results are analyzed, followed by a summary and some concluding thoughts.

II. Literature Review

Given the need for daily transportation and the relative inelasticity of gasoline demand, it is not surprising that volatility in gasoline prices and their relationship to crude oil prices has garnered the attention of both consumers and economists. Table 1 lists some of the studies that have analyzed the relationship between gasoline and crude oil prices. Of the thirteen studies reported in Table 1, ten of them find statistical evidence of "rockets and feathers" price behavior. This finding occurs across several developed countries during different time periods regardless whether the data is monthly, fortnightly, weekly or daily.

The two commonly cited works are by Borenstein, Cameron and Gilbert (1997) and Bachmeier and Griffin (2003). They differ in their data samples and their conclusions. Borenstein, Cameron and Gilbert use semimonthly data and find the "rockets and feathers" asymmetric price behavior while Bachmeier and Griffin use more recent daily data that fails to reject the null hypothesis of a symmetric price response.

Peltzman (2000) finds the asymmetric response of output prices to changes in input costs is a "stylized fact" for many markets. Peltzman analyzes 77 consumer products and 165 producer goods and he finds most of these markets exhibit asymmetric price behavior. In twothirds of the markets he examines, Peltzman shows that output prices increase faster than increases in input prices compared to the fall in output prices when input costs decreased.

How do the studies finding the "rockets and feathers" asymmetric price response explain their statistical results? The asymmetric price behavior of gasoline and crude oil prices has been attributed to the market power, consumer search costs, differing consumer responses to changing prices, inventory management practices, accounting procedures and the presence of adjustment costs. Peltzman (2000) argues that asymmetric price responses are independent of market power. Radchenko (2005, p.708) finds the degree of price asymmetry is inversely related to volatility in crude oil prices and he concludes that "oligopolistic coordination theory is a likely explanation of the observed asymmetry."

But the studies like Bachmeier and Griffin's that refute the "rockets and feathers" hypothesis find "gasoline prices adjust almost instantaneously and symmetrically to crude-oil price changes." They conclude that the retail gasoline market is ". . . a very efficient market with few rigidities (Bachmeier and Griffin, 2003, p. 775)."

III. Methodology and Model Specification

To determine whether gasoline prices respond differently to increases or decreases in the price of crude, two different regression models are estimated. Since the data consist of a year's worth of daily data and autocorrelation could be present, the first set of models tests and corrects for autocorrelation. The second set of regressions is Engle and Granger's (1987) error-correction models that are estimated with ordinary least squares (OLS). If autocorrelation is present, these models will have consistent, but inefficient estimates.

Tests based on models corrected for serial correlation

The price of regular unleaded gasoline on day t, PG_t, is assumed to be a function of the price of gasoline on the previous day (PG_{t-1}), the price of crude on the previous day (PC_{t-1}) and the Dow Jones Industrials on the previous day (DOW_{t-1}) or

$$PG_t = \beta_0 + \beta_1 PG_{t-1} + \beta_2 PC_{t-1} + \beta_3 DOW_{t-1} + \mu_t \; . \tag{1}$$

The error term in Equation (1) is assumed to have an autoregressive format where μ_t is a function of past error terms or $\mu_t = \sum_{j=1}^{k} \rho_j \mu_{t-j} + \varepsilon_t = \rho_1 \mu_{t-1} + \rho_2 \mu_{t-2} + \cdots + \rho_k \mu_{t-k} + \varepsilon_t$ where the lag length k is sufficient to remove any serial correlation and ε_t is white noise. There should be a direct relationship between current gasoline prices and the price of crude oil, an input in production, therefore β_2 should be positive. Likewise, increases in the Dow imply increases in wealth and consumer confidence which result in an increase in the demand for gasoline and higher gasoline prices. Consequently, there should be a direct relationship between the Dow Jones and gasoline prices and β_3 is also expected to be positive. Finally, because of extreme short-run inertia in prices, today's price of gasoline should be directly related to yesterday's price of gasoline and β_1 is expected to be positive.

Suppose the model in Equation (1) was lagged one period and subtracted from the current equation or

$$\Delta PG_t = \beta_1 \Delta PG_{t-1} + \beta_2 \Delta PC_{t-1} + \beta_3 \Delta DOW_{t-1} + v_t \tag{2}$$

where $\Delta PG_t = PG_t - PG_{t-1}$, $\Delta PC_t = PC_t - PC_{t-1}$, and $\Delta DOW_t = DOW_t - DOW_{t-1}$. To test whether the price of gasoline has an asymmetric response to changes in the price of crude, ΔPC_t is partitioned into two different variables, ΔPC_t^+ and ΔPC_t^-. If crude oil prices increase overnight, then $\Delta PC_t^+ = PC_t - PC_{t-1} > 0$. If crude oil prices fall or remain unchanged, then $\Delta PC_t^- = PC_t - PC_{t-1} \leq 0$. After partitioning changes in the price of crude oil into two different variables, Equation (2) can be modified to

$$\Delta PG_t = \beta_1 \Delta PG_{t-1} + \gamma_1 \Delta PC_t^+ + \gamma_2 \Delta PC_t^- + \beta_3 \Delta DOW_{t-1} + \nu_t \ . \tag{3}$$

If price changes are symmetric, then $\gamma_1 = \gamma_2$. If the price is asymmetric and exhibits rockets and feathers behavior, then $\gamma_1 > \gamma_2$. Using standard statistical inference, to test for asymmetric price behavior, the null hypothesis is H_0: $\gamma_1 \leq \gamma_2$, while the alternative hypothesis is H_A: $\gamma_1 > \gamma_2$. Rejection of the null hypothesis confirms the presence of "rockets and feathers" behavior. Again, since time-series data is being used, both Equations (2) and (3) may exhibit autocorrelation, and they must be corrected for serial correlation to obtain efficient estimates and to perform valid statistical inferences.

<u>Tests based on error-correction models</u>

The second approach involves estimating Equation (1) using ordinary least squares and saving $\hat{\mu}_t$, the residuals of this regression. Since time series data may be nonstationary, regressions with such data may lead to spurious results. Unless the data are cointegrated, a regression with nonstationary data can yield spurious results where a model has a very high R^2 but there is no real underlying relationship between the explanatory variables and the dependent variable. Using the cointegration-testing techniques made famous by Engle and Granger, these problems are avoided by using error-correction techniques to modify equation (2) so that

$$\Delta PG_t = \beta_1 \Delta PG_{t-1} + \beta_2 \Delta PC_{t-1} + \beta_3 \Delta DOW_{t-1} + \delta \hat{\mu}_{t-1} + \nu_t \tag{4}$$

where $\hat{\mu}_{t-1}$ is the lagged OLS residual from Equation (1). If oil prices and gasoline prices are cointegated, δ should be negative. Asymmetry in price behavior can be tested by once again partitioning the change in crude oil prices into two separate series to obtain

$$\Delta PG_t = \beta_1 \Delta PG_{t-1} + \gamma_1 \Delta PC_t^{+} + \gamma_2 \Delta PC_t^{-} + \beta_3 \Delta DOW_{t-1} + \delta \hat{\mu}_{t-1} + \nu_t \ . \qquad (5)$$

The results from estimating Equation (5) would indicate asymmetric price behavior and the presence of the "rockets and feathers" phenomenon with the rejection of the null hypothesis that γ_1 is less than or equal to γ_2.

IV. Data, Unit-Root Tests, and Granger-Causality Test

Daily data from 2008 is used to estimate the regressions in Equations (1), (2) (3), (4) and (5). To ensure the data are stationary, the augmented Dickey-Fuller test is performed to verify the data does not have unit roots. In the past, researchers have argued the causality between gasoline and crude prices go both ways. If crude oil prices are a function of gasoline prices, including crude oil prices as an explanatory variable would introduce simultaneity bias. To ensure the causality is unidirectional, running from crude oil prices to gasoline prices, Granger-causality tests are performed on the two data series.

Description of the data

The data consists of daily observations on crude oil prices, gasoline prices and the Dow Jones between January 1, 2008 and December 31, 2008. Prices of regular unleaded gasoline were obtained from Oil Price Information Service and they are plotted in Figure 1.[2] This data consists of surveys of the price at retail pumps and there is an observation for every day of the week, Monday thru Sunday.

The data on crude oil prices is from the Department of Energy's spot prices on West Intermediate crude and the year's data is plotted in Figure 2.[3] The Dow Jones data series consist of weekday observations of the index at the close of the market and they were downloaded from

[2] See http://www.opisnet.com/.
[3] See http://tonto.eia.doe.gov/dnav/pet/pet_pri_spt_s1_d.htm.

Yahoo.[4] When the oil and stock markets were closed on weekends or holidays, there is no new data for these observations. In these cases, the data from the previous close is used as that day's observation.

Unit-Root Tests

Table 2 reports the results of the augmented Dickey-Fuller unit root test on gasoline and crude oil prices. Stationary in each data series was checked using both level data and first differences. In performing the tests, the lag length chosen was the one that minimized the Schwarz Information Criterion.

Using level data, the null hypothesis of a unit root could not be rejected for either series. Referring to Table 2, the t-statistic for gasoline prices was -0.3256 and the test statistic for crude oil prices was -0.7802. Therefore, there is strong statistical evidence that gasoline and crude oil prices are nonstationary in level form.

However, first differences of the data appear to be stationary. The test statistic for first differences in gasoline prices was -4.9259 and the t-statistic for first differences in crude oil prices was -21.9048, both with p-values less than 0.001, leading to a rejection of the null hypothesis of unit roots at the 1 percent level. The main lesson from these results is that the data series are nonstationary in level form and spurious regression results may result unless first differences are used and the data series are cointegrated.

Granger-causality results

The results of the Granger-causality tests reported in Table 3 put to rest concerns about possible simultaneity bias. The results in Table 3 indicate that crude oil prices affect U.S. gasoline prices but the feedback doesn't go the other way: U.S. gasoline prices do not affect crude oil prices.

[4] See http://finance.yahoo.com/.

As Table 3 indicates, the null hypothesis that crude oil prices do not affect gasoline prices is rejected at the one-percent level with an F-statistic of 33.4796. But, the null hypothesis that gasoline prices do not affect crude oil prices, with a test statistic of 1.3634, cannot be rejected, even at the ten-percent level.

V. Estimation Results and Testing for "Rockets and Feathers"

The regression models specified in Equations (1), (2), (3), (4) and (5) were estimated and the various results are summarized in Tables 4, 5 and 6. The results indicate while price asymmetries were not observed over the entire sample, there is evidence reported in Tables 5 and 6 that gasoline and crude oil prices exhibit "rockets and feathers" behavior during a period when crude oil prices were rising in general.

Estimation results for Equation (1)

Table 4 reports the results for six regressions: three of the regressions are corrected for serial correlation and the other three regressions were estimated using only OLS. All six regressions have R^2s over 0.99 and, not surprising, all six regressions have large F-statistics indicating the null hypothesis that all the slope coefficients are simultaneously equal to zero are rejected at the 1 percent level. All the regressions have statistically significant slope estimates with the correct signs. Seventeen of the slope coefficients are statistically different from zero at the one-percent level and the other remaining slope coefficient is statistically significant at the ten-percent level. Bottom line, for a volatile period of wide swings in prices, the models exhibit relatively good fit.[5]

[5] Regressions were estimated including dummy variables indicating the day of the week and the month of year. These dummy variables generally lacked explanatory power and were not included in the final models reported in this paper.

Correcting for serial correlation vs. OLS

The three regressions described in the top half of Table 4 are corrected for serial correlation while the three regressions reported in the bottom half of the table are estimated with ordinary least squares. Referring to the models corrected for autocorrelation, statistical test indicate the inclusion of three past error terms, μ_{t-1}, μ_{t-2} and μ_{t-3}. With only one exception, the estimated ρ_i are statistically significant at the one- or five-percent level.

The models in the bottom half of Table 4 are estimated by ordinary least squares to obtain the regression residuals. Lagged values of these residuals are used as explanatory variables in Table 6. The augmented Dickey-Fuller tests (ADF tests) reported for these regressions in Table 4 indicate the residuals are stationary in level form. This finding adds extra credibility to the cointegration results reported in Table 6.

Tests for parameter stability

One of the novel results of the paper is that the parameter estimates of Equation (1) may be unstable over the entire year of data. As described in the introduction and as seen in Figure 2, between January 1st and July 7th, crude oil prices were generally rising. After July 7th, crude oil prices generally fell. For both estimation techniques - - those correcting for autocorrelation and those estimated with OLS - - three separate regressions were estimated. One regression used the entire data sample. These estimates are reported in the column of Table 4 whose sample is labeled as "Jan 1-Dec 31." The next column in Table 4 reports the estimates for the sample of data between January 1st and July 7th and the regressions results corresponding to the remaining days between July 8th and December 31st are reported in the last column in Table 4.

The Chow tests reported in Table 4 indicate the null hypothesis that the regression estimates are the same over the two subsets of data is rejected. The Chow test for the model corrected for serial correlation is 3.4208 and the Chow test associated with the regression estimated only using OLS is 22.9756. Both of these F-statistics lead to the null hypothesis of parameter stability being rejected at the one-percent level.

Asymmetric price behavior in models corrected for serial correlation

The six regression results reported in Table 5 describe the estimation of the models described in Equations (2) and (3). The key finding here is that the asymmetric "rockets and feathers" behavior occurred in the first part of 2008 between January and July 7th. The null hypothesis that $\gamma_1 \leq \gamma_2$ is rejected at the five-percent level with a t-statistic of 2.2705. There is no evidence of the asymmetric price response for the entire data sample or the sample of data coinciding with a period of declining crude oil prices. The null hypothesis that $\gamma_1 = \gamma_2$ is also rejected for all three regressions, indicating that price asymmetries may indeed exist, but for the entire data sample and the last half of the year, prices exhibit a pattern different than "rockets and feathers" behavior. Indeed, in the last half of the year, gasoline prices may have been more responsive to declines in crude oil prices than to increases in the price of crude.

The estimation results in Table 5 still indicate problems with autocorrelation as the regression include two lagged error terms. The six regressions generally exhibit goodness of fit with R^2s lying between 0.61 and 0.76. The parameter estimates were generally statistically significant and of the correct sign.

Asymmetric price behavior in models with error-correction mechanism

The estimation results of the models in described in Equations (4) and (5) are reported in Table 6. Several key results are found in this table. First, like the results in Table 5, these models also indicate the presence of price asymmetries of the "rockets and feathers" type in the first half of 2008. The t-statistic was 1.5379, indicating that the null hypothesis that $\gamma_1 \leq \gamma_2$ is rejected at the ten-percent level. The test statistic is almost significant at the five-percent level with a p-value of 0.0629. In this time period with generally rising crude oil prices, the gasoline prices increased rapidly when crude oil prices increased, but fell slower when crude oil prices decreased.

Second, the null hypothesis of symmetric price changes cannot be rejected for the entire sample and the sample consisting of the first part of the year; but, the null hypothesis of equal slope coefficients is rejected for the second half of the year. Once again, in this time period, there is evidence of a direct relationship between crude oil prices and gasoline prices, but the change in gasoline prices were larger when crude oil prices fell.

Third, the coefficient on the lagged residual term, δ, is always negative and significant, indicating that gasoline and crude oil prices are cointegrated. This result indicates, questions about possible asymmetries aside, that gasoline prices do adjust to changes in crude prices with a lag. Once again the six regressions reported in Table 6 indicate generally good fit with relatively high R^2s between 0.62 and 0.76 and statistically significant slope coefficients.

VI. Concluding Thoughts

For those who believe in the presence of "rockets and feathers" asymmetries in prices and for those who are fundamentally opposed to this hypothesis, the regressions reported in this paper give a mixed bag of results. Using the entire data sample of all daily prices in 2008, there is no evidence of the "rockets and feathers" type of price asymmetries. This a particularly significant finding given the instability of crude oil and gasoline prices, the rapidity of their ascent to record highs and how fast they plummeted to levels that are stunningly low for current history. However, there is evidence that the estimated regressions estimates are unstable over the entire data sample. This calls into question the finding that gasoline prices respond symmetrically to increases and decreases in the price of crude.

If the entire data set is partitioned into two subsets, regression results find "rockets and feathers" price asymmetries in a time period when crude oil prices were generally rising. In this time period, retail prices increased because of higher input prices. But consumers attuned to higher retail prices would search more aggressively with rising prices, so the price increases would not get out of hand. However, conditioned by a period of rising crude prices, the few times crude oil prices fell, retail outlets could slowly lower prices, because consumers were not as aggressive on their search for lower gasoline prices.

Using data from the last six months, regression results indicate that gasoline prices fell faster in a period of falling prices. The results from the partitioning of data suggest that consumer search techniques and retail pricing may differ in a regime of considerable increases in input prices and a separate regime of generally falling input prices.

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Table 1
Studies Testing for Asymmetric Response between Gasoline and Crude Oil Prices

Study	Region	Frequency of Data	Time Period	Rockets and Feathers Behavior?
Bacon (1991)	U.K.	Semimonthly	6/82 – 1/90	Yes
Karrenbrock (1991)	U.S.	Monthly	1/83 – 12/90	Yes
Borenstein, Cameron, and Gilbert (1997)	U.S.	Semimonthly	3/86 – 12/92	Yes
Balke, Brown and Yücel (1998)	U.S.	Weekly	1/87 – 8/96	Yes
Eltony (1998)	U.S. & U.K.	Monthly	1/80 – 6/96	Yes
Godby, Lintner, Stengos and Wandschneider (2000)	Canada	Weekly	1/90 – 12/96	No
Galeotti, Lanza and Manera (2002)	Germany, France, Italy, Spain, UK	Monthly	1/85 – 12/00	Yes
Bremmer and Christ (2002)	U.S.	Monthly	2/76 – 12/01	No
Bremmer and Christ (2002)	U.S., U.S. regions, Selected U.S. states and cities	Weekly and Daily	1/97 – 4/02	Yes
Bachmeier and Griffin (2003)	U.S.	Daily	1/85 – 12/98	No
Radchenko (2005)	U.S.	Weekly	3/91 – 2/03	Yes
Noel (2007)	Toronto, Canada	Daily	2/01 – 6/01	Yes
Honarvar (2009)	U.S.	Monthly	9/81 – 12/07	Yes

Table 2
Augmented Dickey-Fuller Tests: Daily Data, 2008

Level Data			*First-Differenced Data*		
Variable	t-statistic	Lags	Variable	t - statistic	Lags
Regular Gasoline Price	-0.3258 (0.9897)	3	Regular Gasoline Price	-4.9259* (0.0003)	2
Crude Oil Price	-0.7802 (0.9654)	1	Crude Oil Price	-21.9048* (0.0000)	0

* indicates the null hypothesis that the time series has a unit root is rejected at the 1% level. P-values are in parentheses. The regressions reported in this table include both an intercept and a time trend as explanatory variables.

Table 3
Granger Causality Tests: Daily Data, 2008

Null Hypothesis	F-Statistic
Crude oil prices do not Granger cause regular gasoline prices	33.4796* (0.0000)
Regular gasoline prices do not Granger cause crude oil prices	1.3634 (0.2571)

* indicates the null hypothesis is rejected at the 1% level. P-values are in parentheses. Each regression includes two lags of the endogenous variables.

Table 4
Dependent Variable: Regular Gasoline Price (Daily Data, 2008)

Regressions Corrected for Serial Correlation

Parameter	Explanatory Variable	Samples		
		Jan 1 – Dec 31	Jan 1 – Jul 7	Jul 8 – Dec 31
β_0	Constant	-0.0265*** (-1.8107)	-0.0356 (-1.1419)	-0.0589** (-2.4328)
β_1	Regular Gasoline Price$_{t-1}$	0.9568* (151.8856)	0.9228* (95.8553)	0.9628* (109.4068)
β_2	Crude Oil Price$_{t-1}$	0.0011* (6.9352)	0.0020* (8.7849)	0.0007* (3.0916)
β_3	Dow Jones$_{t-1}$	0.0049* (3.1542)	0.0068* (2.9053)	0.0094* (2.9754)
ρ_1	ε_{t-1}	0.8182* (15.6809)	0.8083* (10.7227)	0.7552* (10.0333)
ρ_2	ε_{t-2}	-0.2570* (-3.9051)	-0.3300* (-3.6172)	-0.2160** (-2.3182)
ρ_3	ε_{t-3}	0.2029* (3.8788)	0.0364 (0.4882)	0.2382* (3.1038)
	R^2	0.9999	0.9997	0.9999
	DW	1.9897	2.0035	1.9685
	F-Statistic	428306.0†	113928.8†	236496.3†
	N	362	185	177
	Chow Test	3.4208†		

OLS Estimates (Results Used Later in Error Correction Models)

Parameter	Explanatory Variable	Samples		
		Jan 1 – Dec 31	Jan 1 – Jul 7	Jul 8 – Dec 31

β_0	Constant	-0.0498* (-7.4234)	-0.0697* (-3.2873)	-0.1298* (-9.4956)
β_1	Regular Gasoline $Price_{t-1}$	0.9669* (283.0759)	0.9216* (110.0174)	0.9680* (215.3412)
β_2	Crude Oil $Price_{t-1}$	0.0008* (8.1118)	0.0020* (10.1441)	0.0003*** (1.8447)
β_3	Dow $Jones_{t-1}$	0.0067* (9.6883)	0.0094* (5.8880)	0.0190* (9.5772)
	R^2	0.9997	0.9995	0.9998
	DW	0.5827	0.8161	0.7158
	F-Statistic	399780.0†	134574.6†	255234.0†
	N	365	188	177
	ADF Test: Residual	-5.9573*	-8.2647*	-6.2130*
	Chow Test	22.9756†		

t statistics in parentheses. *, **, and *** indicate the two-tailed t-tests reject the null hypothesis at the 1%, 5%, and 10% level of significance, respectively. † indicates the F-tests reject the null hypothesis at the 1% level, respectively.

Table 5

Dependent Variable: Change in Regular Gasoline Price (Daily Data, 2008)

Regressions Corrected for Serial Correlation

Parameter	Explanatory Variable	Samples					
		Jan 1–Dec 31	Jan 1–Dec 31	Jan1-Jul 7	Jan 1-Jul 7	Jul 8-Dec 31	Jul 8-Dec 31
β_1	ΔRegular Gasoline Price$_{t-1}$	0.8902* (39.6221)	0.8750* (37.0109)	0.7544* (15.5579)	0.7105* (13.4741)	0.9238* (35.7010)	0.8803* (27.9905)
β_2	ΔCrude Oil Price$_{t-1}$	0.0011* (6.8756)		0.0019* (7.7490)		0.0008* (3.4058)	
γ_1	ΔCrude Oil Price$^{+}_{t-1}$		0.0008* (3.2530)		0.0023* (7.4287)		0.0001 (0.2176)
γ_2	ΔCrude Oil Price$^{-}_{t-1}$		0.0015* (6.7327)		0.0011* (2.8065)		0.0013* (4.3016)
β_3	ΔDow Jones$_{t-1}$					0.0067** (2.0388)	0.0051 (1.5380)
ρ_1	μ_{t-1}	-0.0319 (-0.5987)	-0.0250 (-0.4652)	0.1276 (1.5711)	0.1579*** (1.9115)	-0.1206 (-1.6175)	-0.0865 (-1.1253)
ρ_2	μ_{t-2}	-0.2819* (-5.3541)	-0.2782* (-5.2597)	-0.2536* (-3.3195)	-0.2512* (-3.2905)	-0.3198* (-4.2390)	-0.2993* (-3.9121)
	R^2	0.7541	0.7579	0.6100	0.6207	0.6921	0.7041

	DW	2.0111	2.0092	2.0550	2.0450	1.9916	1.9804
	N	362	362	185	185	177	177
	H_0: $\gamma_1 \leq \gamma_2$ (1-tail t-test)		-2.3365		2.2705††		-26.2368
	H_0: $\gamma_1 = \gamma_2$ (F-test)		5.4649‡‡		5.1480‡‡		6.8697‡

t statistics in parentheses. *, **, and *** indicate the two-tailed t-tests reject the null hypothesis at the 1%, 5%, and 10% level of significance, respectively. †† indicates the one-tail t-test rejects the null hypothesis at the 5% level. ‡ and ‡‡ indicate the null hypothesis of the F-test is rejected at the 1% and 5% level, respectively.

Table 6
Dependent Variable: Change in Regular Gasoline Price (Daily Data, 2008)

Error Correction Models

Parameter	Explanatory Variable	Samples					
		Jan 1–Dec 31	Jan 1–Dec 31	Jan1-Jul 7	Jan 1-Jul 7	Jul 8-Dec 31	Jul 8-Dec 31
β_1	ΔRegular Gasoline Price$_{t-1}$	0.9694* (27.7041)	0.9563* (26.1149)	0.8920* (15.8998)	0.8568* (14.1883)	0.9875* (23.8915)	0.9423* (19.9370)
β_2	ΔCrude Oil Price$_{t-1}$	0.0012* (6.8113)		0.0022* (8.8513)		0.0006** (2.4140)	
γ_1	ΔCrude Oil Price$^{+}_{t-1}$		0.0009* (3.7309)		0.0025* (7.9085)		0.00002 (0.0602)
γ_2	ΔCrude Oil Price$^{-}_{t-1}$		0.0014* (5.6618)		0.0016* (3.7714)		0.0011* (3.0733)
β_3	ΔDow Jones$_{t-1}$					0.0072** (2.2184)	0.0060*** (1.8018)
δ	Error Correction Term	-0.2911* (-5.7184)	-0.2780* (-5.3407)	-0.3701* (-4.4967)	-0.3459* (-4.1442)	-0.3499* (-4.9290)	-0.3063* (-4.1404)
	R^2	0.7574	0.7584	0.6201	0.6250	0.7017	0.7080
	DW	1.8267	1.8267	1.6022	1.5801	1.8711	1.8532

	N	364	364	187	187	176	176
	H_0: $\gamma_1 \leq \gamma_2$ (1-tail t-test)		-1.2040		1.5379†††		-1.9218
	H_0: $\gamma_1 = \gamma_2$ (F-test)		1.4486		2.3697		3.6984‡‡‡

t statistics in parentheses. *, **, and *** indicate the two-tailed t-tests reject the null hypothesis at the 1%, 5%, and 10% level of significance, respectively. ††† indicates the one-tail t-test rejects the null hypothesis at the 10% level. . ‡‡‡ indicates the null hypothesis of the F-test is rejected at the 10% level.

Figure 1
The Price of Unlead Regular Gasoline at the Pump

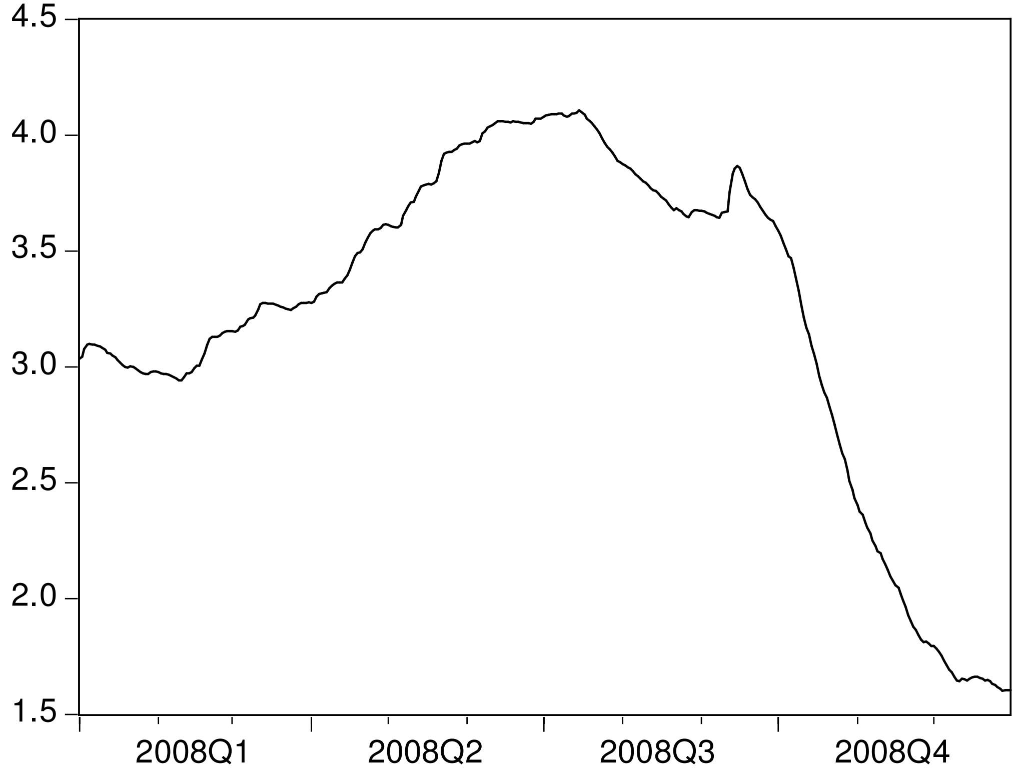

Figure 2
The Price of West Texas Intermediate Crude Oil