Distribution Agreement

Hongbo Liu April 11, 2013

A Comprehensive Analysis of

Determinants of the US National Retail Price of Gasoline

by

Hongbo Liu

Latika Lagalo
Adviser

Department of Economics

Latika Lagalo

Adviser

Shun Yan Cheung

Committee Member

Michael McCormick

Committee Member

2013

A Comprehensive Analysis of

Determinants of the US National Retail Price of Gasoline

By

Hongbo Liu

Latika Lagalo

Adviser

An abstract of
a thesis submitted to the Faculty of Emory College of Arts and Sciences
of Emory University in partial fulfillment
of the requirements of the degree of
Bachelor of Arts with Honors

Department of Economics

2013

Abstract

A Comprehensive Analysis of Determinants of the US National Retail Price of Gasoline
By Hongbo Liu

This investigation examines the multiple factors that lead to the pricing of the national average price of regular gasoline in the United States through a three dimensional analysis focusing on pricing, supply, and technology. In addition to time series analysis on trend and seasonality, three models corresponding to factors relating spot prices, quantities of various raw and refined petroleum products and refining technology are constructed to determine how individual factors impact the pricing of retail regular grade motor gasoline in the United States. Using weekly data from 1995 to 2010 published by the Energy Information Administration, ordinary least squares (OLS) regressions are conducted and the strengths of the constructed models are evaluated. Results indicate that the regular gasoline retail price is impacted by the WTI Index price, the New York Harbor Conventional gasoline spot price, the retail price of premium gasoline, the US domestic production of crude oil, the US Stocks of gasoline, the total products supplied for all petroleum products, the gross input into refineries, the refinery operable capacity, and the percent utilization of the refinery operable capacity. Additionally, it was determined that seasonality did not have a significant impact on retail gasoline pricing but the price itself for any week is strongly influenced by the price of the immediately preceding week.

A Comprehensive Analysis of

Determinants of the US National Retail Price of Gasoline

By

Hongbo Liu

Latika Lagalo

Adviser

A thesis submitted to the Faculty of Emory College of Arts and Sciences
of Emory University in partial fulfillment
of the requirements of the degree of
Bachelor of Arts with Honors

Department of Economics

2013

Acknowledgements

I am most grateful for the continuous guidance and support offered by Professors Latika Lagalo, Shun Yan Cheung, and Michael McCormick throughout this past year. Their individual expertise in their respective fields uniquely combined to enable this investigation that expanded beyond the confines of traditional economics literature. I am also thankful for the encouragement and support from friends and family that reinforced my drive and determination. This work would not have been possible without any one of you.

Table of Contents

Contents:

List of Figures:

List of Tables

I. Introduction

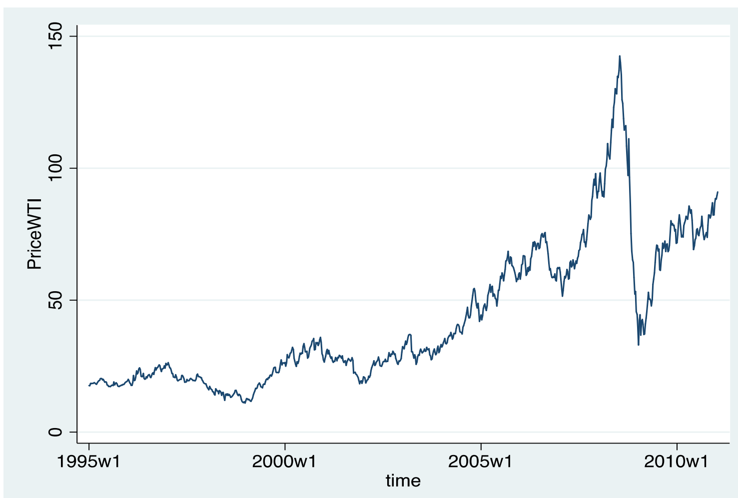
With the rapidly expanding economy in emerging markets throughout the world, global demands for sources of energy has drastically impacted the United States domestic market. As standards of living improve in developing nations, competition for non-renewable sources of fuel such as crude oil has left deep repercussions for the average consumer around the global. This impact is well represented by the national average price of regular gasoline, a measure of the average cost of gasoline to the ultimate consumer at the pump. Yet, despite the simplicity of the metric, the actual complexity of the various factors that goes into this pricing is perhaps even more convoluted than the route gasoline takes from the ground to the tank. Through a three dimensional analysis focusing on pricing, supply, and technology, this investigation will examine the multiple factors that lead to the pricing of the national average price of regular gasoline in the United States.

For purposes of this investigation, it is important to draw a distinction between regular gasoline from other grades of gasoline products, namely premium gasoline as it is an explanatory variable in this investigation. Gasoline, along with other refined petroleum products, are most easily classified by their research and motor octane number (RON, MON) which provide a measure of the anti-knocking behavior of a particular grade of fuel (Pasadakis, Gaganis, and Foteinopoulos 2006). The higher the octane number, the smoother the engine runs because of its ability to resist spontaneous detonation. The octane number of a commercially available gasoline is determined by the ASTM- prescribed research octane number testing method, where knocking is measured with a CFR engine whose compression ratio is variable (Ichikawa et al. 1992). In the United States at most gas stations, the quality of the gasoline is given by the Anti-Knocking Index (AKI) equivalent to the average of the RON and MON. Most commonly in non-high elevation regions gasoline with an octane rating of 87 is defined as regular while those of 89 and 93 are defined as mid-grade and premium, respectively.

The very sources of these differences in fuel rating are the results of refining oil. After crude oil is drilled out of the ground, it must be processed and refined into more useful products such as gasoline, diesel fuel, heating oil, kerosene, etc. For the typical refinery, higher profit margins from transportation fuels motivate a conversion of crude oil to as much gasoline, diesel, and jet fuels as economically practical (Gary and Handwerk 2001). Consequently, other crude derivatives such as lubricating oils, refrigeration and transformer oils, and petrochemical feedstock amount to less than five percent of the total output for oil refined by US refineries as a whole.

As such, the relationship between the price of crude oil directly and the price of gasoline has been extensively studied for the past century since the advent of petroleum products. Consequently, global financial markets have developed a strong focus towards the trade of this commodity as well as financial instruments to facilitate its liquidity. In 1960, the formation of The Organization of the Petroleum Exporting Countries (OPEC) led to the first stabilized pricing of oil in international trade. Its impact, resonated globally through the four decades since its inception, has to this day significantly impacted global oil supplies and thus prices. Nonetheless, as presented in Figure 1, the price of crude oil readily fluctuates with

Figure 1: WTI Crude Prices January 1995 – December 2010



economic as well as political shocks.

In order to facilitate global trade of this commodity, benchmark indices are used to differentiate grade and location. In North America, the most commonly used measure for a barrel of oil is the West Texas Intermediate (WTI) index which is traded on the New York Mercantile Exchange. It is a light crude oil with properties that make it ideal for refining in the United States. Other benchmarks around the world include the Brent Crude, Dubai, Tapis, and the OPEC basket. For this investigation with data from the US Energy Information Administration (EIA), the imported refiner acquisition cost which is the weighted average cost of all oil imported into the country will be defined as the "world oil price".

Oil prices alone, however, are insufficient to explain the complex factors that lead to the National Average Retail Price of Gasoline. While multiple previous investigations have focused on how each factor such as household demand (Schmalensee and Stoker 1999), market power/wholesale of gasoline (Hastings and Gilbert 2005), as well as price collusion and deregulation (Goto and McKenzie 2002), no across the board effort has been made to investigate the interplay between the various factors that systematically price gasoline to the end consumer in the United States national market. Set against an almost unpredictable growing global demand for energy, this investigation will attempt to analyze the dynamic interplay of multiple factors that impact US retail gasoline prices via a comprehensive and holistic approach. In detail, it will take a horizontal approach by looking at the factors that impact across the gasoline supply chain in terms of financial, supply, and technology related variables. The interplay between the independent variables within each model will subsequently allow for the construction of empirical models that enables a forecast of gasoline retail prices.

II. Literature Review

Previous investigations on gasoline prices have predominately focused on the relationship between crude oil prices, refining, and end-user gasoline demand in a macroeconomic context. James Hamilton famously investigated multiple trends that correlated oil shocks to recessions in the United States (Hamilton 1983) and further detailed the correlation of historical oil prices (Hamilton 1996). His work suggested that oil shocks affect the macroeconomy primarily by depressing demand for key consumption and investment goods (Hamilton 1996). In contrast, Hooker (1996) previously proposed that the linear relation between oil prices and output first proposed by Hamilton (1983) and the asymmetric relation based on oil price increases alone advocated by Mork (1989) is consistently observed economic performance. Hamilton strengthened his previous argument and somewhat accurately predicted that within ten years of his publication, turmoil in the Middle East will produce another major disruption to world petroleum supplies that will produce a recession in the United States (Hamilton 1996).

Linking crude oil supply to prices of overall petroleum products, Kaufmann and Laskowski through an econometric analysis studied the asymmetric relation between the price of crude oil and motor gasoline to conclude that it is generated by refinery utilization rates and inventory behavior. Their work suggested that the asymmetric relation between the price of crude oil and home heating oil is generated by contractual arrangements between retailers and consumers and may occur in efficient markets (2005). This work largely expanded upon tests for price patterns in retail gasoline markets predicted using super game models of implicit collusion among firms (Borenstein and Shepard 1993) and explained by production/inventory adjustment lags and market power of some sellers (Borenstein, Cameron, and Gilbert 1997). In a subsequent model introduced by Borenstein and Shepard, they additionally expand on the idea that costly adjustment of production and costly inventories implies that wholesale gasoline prices will respond with a lag to crude oil cost shocks. However, deviating from traditional models of menu costs, imperfect information, or long-term buyer/seller relationships, their new model also predicted that futures prices for gasoline adjusts incompletely to crude oil price shocks that occur close near the expiration date of the futures contract (Borenstein and Shepard 2002).

This conception of gasoline prices responding asymmetrically to crude prices have further been observed in multiple localized markets. In Salt Lake City, wholesale and retail gasoline price data demonstrated evidence of price asymmetry during periods of average weekly wholesale price changes but evidence of price symmetry during market shocks (Duffy-Deno 1996). When expanded to the entire United States, it was identified by a Crouching Error Correction Model (CECM) that there is only evidence of co-integration between positive components of crude oil prices and negative components of gasoline prices. This finding is instrumental because it suggests that in the long run gasoline prices are more influenced by the technological changes on the demand side than crude oil price movements on the supply side (Honarvar 2009).

Elsewhere around the globe, this same theory of asymmetric pricing has been tested in Canada and the United Kingdom. Godby et al. applied a Threshold Regression model to test for asymmetric pricing in the retail gasoline market in Canada. For the time period January 1990 to December 1996, however, they were unable to find evidence to support the presence of asymmetric behavior, suggesting differences in market structure between Canada and other countries such as the United States (Godby et al. 2000). In contrast, in the United Kingdom, price asymmetry was found via evidence that indicated that the speed of adjustment of UK retail gasoline prices to cost changes is more rapid when costs rise than when they fall, leading to the 'rockets and feathers' hypothesis of asymmetric speeds of adjustment of UK retail gasoline prices (Bacon 1991).

Apart from the impact of crude oil prices on gasoline prices, the effect of other factors such as differentiation, inventory, and vertical integration has been extensively but individually studied for multiple geographies and markets. Studying within the overall context of vertical and horizontal product differentiation that explains observed price-cost margin differentials for goods of various qualities, Barron et al. analyzed the reasons for the premium behind premium gasoline. The authors found that differences in price-cost margins positively depend on consumers' average valuation for incremental increases in quality (Barron, Taylor, and Umbeck 2000). This concept of pricing is similarly explored by Considine who introduced a structural model of markup pricing under joint production with quasi-fixed inputs of capital, labor, and inventories. Finding substantial markups for jet fuel and gasoline while relatively lower markups for residual fuel, distillate, and other petroleum products, the model further suggested that wholesale markets in the U.S. for refined petroleum products may not be competitive (Considine 2001). Additionally looking at the market for refined petroleum products from a supply and demand for storage perspective, Considine and Heo concluded that under higher input prices, refiners reduce their stocks of crude oil but increase their product inventories, thus leading to cost smoothing (2000).

Behaviors of refineries and their impact on wholesale prices of gasoline were investigated by Hastings and Gilbert in the context of market power and vertical integration. Looking at US West Coast gasoline refineries and retail markets, the authors used discrete and differential changes in the extent of vertical integration to test for incentives to raise rivals' costs. Their empirical analysis found that mergers in the gasoline industry that increase the extent of vertical integration lead to increases in wholesale prices as a consequence of the incentive to raise rivals' costs. Hence, changes in vertical market structure can have significant impacts on upstream firm conduct and equilibrium prices (Hastings and Gilbert 2005).

Additional changes that are both horizontally and vertically transmitted through the oil supply chain were investigated by Kaufmann et al. via vector error correction models that represent relationships among the price of crude oil, refinery utilization rates, stocks of crude oil and of gasoline, the price of motor gasoline, and the price of a substitute fuel, natural gas. In support of previous literature, the investigators found that the price of crude oil is an important gateway for disturbances to the oil supply chain and its change will affect inventory behaviors, refinery utilization rates, as well as the price of gasoline (Kaufmann, Dees, and Mann 2009). The investigation of Kaufmann et al. parallels that of Holmes et al. which employed a pair-wise approach to examine regional integration in the US gasoline market (Holmes, Otero, and Panagiotidis 2013) but more importantly highlights a significant need for a comprehensive and systematic investigation of multiple factors that affect the price of motor gasoline in the United States, hence the purpose of the subsequent investigation.

III. Data Description

Data used throughout this investigation, obtained via the United States Energy Information Administration (EIA), are independent and impartial energy information disseminated by the EIA to promote sound policymaking, efficient markets, and public understanding of energy and its interaction with the economy and the environment. With a focus on petroleum and other liquid fuels, the data for this analysis consists of time series for independent variables that represent elements of prices, crude reserves and production, refining and processing, imports/exports and movements, stocks, and consumption/sales.

The overall data set compiled for this investigation comprises of weekly time series data from January 1995 to December 2010 for a total of 835 observations per variable. The dependent variable, the Weekly U.S. Regular All Formulations Retail Gasoline Prices is presented in units of Dollars per gallon. A preliminary analysis on this variable versus its change in time (Figure 2) demonstrates a trend of growth overtime subject to large fluctuations. These large fluctuations readily correlate with occurrence of global economic recessions, as predicted by Archanskaia et al. who identified that supply-driven oil price shocks have a negative impact on the macroeconomic activity of countries such as the US that are net consumers of oil (2012).

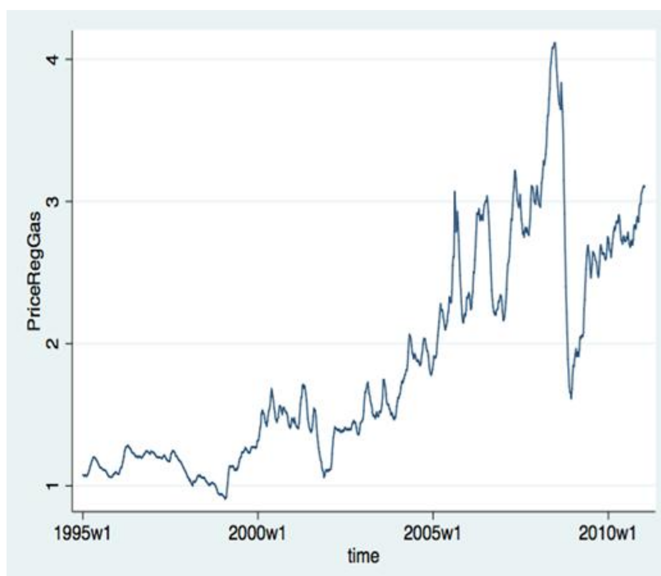


Figure 2: Price of Retail Gasoline in the US, January 1995 – December 2010

The independent variables for this investigation can be categorized into the three areas of focus, namely price, quantity, and technology. This systematic separation of these three major contributing factors to gasoline price allows for the isolation of each factor, consequently enabling a robust analysis that captures individual contribution to the overall price. Further, this division matches this investigation to the overall context of economic growth in the areas of financial allocation, quantity/demand, and technological advancement. Independent variables within each category are detailed as presented subsequently.

3.1 Price

The effect of various prices on the overall price of gasoline will be analyzed via financial indices prices for crude oil, conventional gasoline, retail prices of higher grades of motor gasoline and the retail price of diesel. Price indices for crude oil capture the effect of the raw material pricing in world financial markets while price indices for conventional gasoline capture the effect from prices changes for gasoline in the financial markets. The retail prices of premium gasoline may highlight the effects of short term substitution since the products are readily substitutable in the short run. The retail price of diesel reflect upon the effects of long term substitution; while gasoline engines cannot use diesel as a fuel source, diesel engines are substitutes for gasoline engines and hence in the long run can be used in place of gasoline engines.

3.2 Quantity

With respect to quantity, the directly relationship between price and demand is encapsulated by factors that detail production, stock/inventory, supply, imports, and exports. Specifically, the quantities of domestic crude oil production and domestic crude oil stock will impact the quantity of crude oil available to the United States as a nation. The quantity of gasoline in stock will most directly influence the supply of gasoline for retail use. Two additional factors, crude oil days of supply and gasoline days of supply, calculated by the EIA by taking the current stock level and dividing by product supplied can be used as a measure of the adequacy of inventories. The import quantities of crude oil and gasoline can be used as an additional dimension to capture demand while the export quantities reflect possible excesses in the system. Moreover, the contrast between import/export quantities of raw crude versus refined gasoline serve as a proxy for technology availability and utilization domestically as it would be appropriate to import more raw products if refineries are underutilized and to import more finished products if refineries are at maximum capacity. Finally, two independent variables describe the total gasoline supplied and total petroleum products supplied as they are expected to capture the overall effects of supply on national retail price.

3.3 Technology

While the pricing and quantity of crude oil has attracted significant focus in previous studies on gasoline pricing, this investigation will also devote a greater focus on the technology that refines raw crude oil into finished petroleum products. These factors that govern the quantity of inputs as well as the capacity and efficiency of refineries will elucidate the impact of refining operations on the price of retail gasoline. Specifically, crude inputs will describe the total crude oil put into processing units at refineries while gross inputs will describe the crude oil, unfinished oils, and natural gas plant liquids put into atmospheric crude oil distillation units. In addition, operable capacity will detail the amount of capacity in operation measured in barrels per day to capture the total domestic capacity to refine oil and its impact on end-user price. Finally, percent utilization, calculated by dividing gross inputs to these units by the operating/operable refining capacity of the unit, represents the utilization of all crude oil distillation units. In combination, these factors serve to implicate the impact of technology utilization on the price of retail gasoline to the end-use consumer.

IV. Empirical Methods

4.1 Hypothesis

As the previous literature reviews indicate a lack of an existing comprehensive analysis and motivated by the need to systematically investigate the interplay between the multiple determinants of the price of motor gasoline in the United States, the following hypothesis are formulated in order to examine the effects of prices of commodities, quantity/supply of petroleum products, and technology in refining on the national retail price of gasoline:

H1. The national retail price of gasoline is impacted by prices of both crude oil and all other refined petroleum products. Specifically, it is significantly influenced by with WTI index, the New York Harbor conventional gasoline spot price, and Premium gasoline and diesel retail prices.

H2. The national retail price of gasoline is related to the quantity of gasoline available. Specific, it is partially determined by the quantity of domestic production, crude oil stock, gasoline stock, crude oil days of supply, gasoline days of supply, crude oil imports, gasoline imports, total gasoline supplied, and total petroleum products supplied. Further, the national retail price of gasoline is also influenced by both the quantity of crude oil exports and total petroleum products exports.

H3. The national retail price of gasoline is significantly impacted by efficiency in technology. Specifically, it is affected by crude inputs, gross inputs, operable capacity, and percent operable utilization.

4.2 Methodology

For the analysis, the dependent variable will be expressed as the logarithm of the retail price of regular gasoline. Logarithms are used here because expressing a time series as a base ten logarithm allows for a representation of a growth rate. Further, the logarithmic transformation will minimize the risk of heteroskedasticity for variables that are always positive. Since the presence of heteroskedasticity can create biased standard errors that lead to biased inference for statistical tests of significance, this approach mitigates possible type II errors where a false null hypothesis fails to be rejected. Finally, taking logarithms helps make a time series stationary by stabilizing the variance. This transformed variable, namely logPriceReggas, will then be regressed against time to evaluate any statistical significance with the time variable. An autocorrelation analysis will be applied to test for the effects of lags, in this case the price of the previous period, on predicting the subsequent price of regular gas. Specifically, the first lag will be used because the regression of interest entails looking at how the price immediately before the current price affects the current price. While additional lags may be analyzed, the findings of Al-Gudhea et al. concluded that price adjustments to shocks are transmitted into retail pricing within 2 days (2007). Hence, since weekly data is used in this investigation and pricing occurs within 2 days, a lag of 1 week, or seven days, is readily sufficient to capture the impact of the previous price.

In addition, seasonality will also be analyzed to determine if any influence from seasonality is present in the dependent variable. Due to the nature of the time series data used, the presence of seasonality can create periodic fluctuations. For data on retail prices of gasoline, it is possible to exhibit seasonality from differences in demand in summer and winter. As a consequence, the seasonality factor must be accounted and incorporated into the models if present.

Subsequently, three models will be developed via three ordinary least squares (OLS) regressions. OLS regression can be appropriately applied in this investigation because its requirements of constant mean, constant variance, and zero autocorrelation are adequately satisfied by the techniques of using logarithms and lags of the dependent variable. As an overview, each OLS regression will regress the dependent variable, national retail price of regular gasoline, against all other included independent variables. Accordingly, the first model on spot prices on retail price of gasoline is developed by regressing the retail price of gasoline with the WTI index for crude oil, the New York Harbor Index for conventional gasoline, the national average retail price of premium gasoline, and the national average retail price of diesel fuel. The resulting regression is presented in the Appendix, Table 4: Regression 1a, 1b and is given by the equation:

Model 1 - Spot Price:

$$\log(Price) = \beta_0 + \beta_1 WTI + \beta_2 NYCH + \beta_3 PricePremium + \beta_4 PriceDiesel + \beta_5 \log(Price_{t-1})$$

Following the regression, the strength of the model was evaluated by constructing a partial autocorrelation correlogram (Figure 3).

The next model on quantity is developed by regressing the retail price of gasoline with the domestic production of crude oil, the crude oil stock, the gasoline stock, the crude oil days of supply, the gasoline days of supply, the quantity of crude imports, the quantity of gasoline imports, the quantity of crude exports, the quantity of gasoline exports, the total quantity of gasoline supplied, and the total quantity of all petroleum products supplied. The resulting regression is presented in the Appendix, Table 6: Regression 2a, 2b and is given by the equation:

Model 2 - Quantity:

$$\begin{aligned}\log(Price) = {} & \beta_0 + \beta_1 DomesticProd + \beta_2 CrudeOilStock + \beta_3 GasolineStock \\ & + \beta_4 CrudedaysofSupply + \beta_5 GasdaysofSupply + \beta_6 CrudeImports \\ & + \beta_7 GasImports + \beta_8 CrudeExports + \beta_9 TotalExports \\ & + \beta_{10} TotalGasSupplied + \beta_{11} TotalProductsSupplied + \beta_{12} \log(Price_{t-1})\end{aligned}$$

As in model 1, following the regression, the strength of the model was evaluated by constructing a partial autocorrelation correlogram (Figure 4).

Correspondingly, the third model on technology is developed by regressing the retail price of gasoline with the quantity of crude oil inputs, the gross inputs of all refinery products, the operable capacity, and the percent operable utilization. Likewise, the resulting regression is presented in the Appendix 1, Table 8: Regression 3a, 3b and is given by the equation:

Model 3 - Technology/Utilization:

$$\begin{aligned}\log(Price) = {} & \beta_0 + \beta_1 CrudeInputs + \beta_2 GrossInputs + \beta_3 OperableCapacity \\ & + \beta_4 PercentOperableUtilization + \beta_5 \log(Price_{t-1})\end{aligned}$$

As in the previous models, the strength of the model was evaluated by constructing a partial autocorrelation correlogram (Figure 5).

V. Results and Discussion

5.1 Seasonality

The possible effects of seasonality were first explored to ensure that the dependent variable is not subjected to seasonal fluctuations. Fifty-three dummy variables were generated corresponding to each week of the year. This was regressed against the log of the price of regular gasoline. The resulting regression (Table 3) indicate that seasonality is not significant because no independent variable corresponding to the repeating weeks within the 15 year period was statistically significant at the α=0.05 level. This finding suggests that seasonality is not significant to the price of regular gasoline in the United States as a whole, reflecting the fact that numerous uses for gasoline are independent of seasons.

5.2 Time Trend Analysis

Having determined that seasonality is not a factor that impacts retail gasoline prices in the United States, attention is then directed to the impact of time and the previous price. Appropriately employing an AR (1) Model to account for the price of the previous period, the dependent variable is regressed against a time variable as well as its first lag. The ensuing regression (Table 10: regression 4) indicates that time itself is not a statistically significant predictor of the retail price of gasoline but the previous price is strongly significant in influencing the subsequent price. In other words, the change in the retail price of gasoline is readily affected by the previous price instead of the advancement of time. This finding is well within expected behavior of retail prices; while the price is freely able to change based on market conditions, these conditions are unrelated to time. As a result, the best indicator of tomorrow's price is today's price, hence the autoregressive nature of the retail price as evidenced in this case.

5.3 Price

For each model, the significance of each independent variable can be evaluated from the p-values of each variable at the $\alpha=0.05$ level. In the first model focused on spot prices, all variables except for the retail price of diesel fuel were found to be significant. This is well within reason as for diesel fuel, though it is derived from the same crude oil, its end-use application is widely different from gasoline in a manner that they cannot be readily substituted in the short run. While it is possible in the long run for the substitution to occur by converting all current gasoline engines to diesel types, the focus of this investigation centers on the instantaneous variables that price retail gasoline. Hence, dropping this variable in the regression, the resulting regression indicates that:

$$\log(Price) = -.0385 + (.0005297)WTI + (-.0852)NYCH + (-.00473)PricePremium + (0.962)\log(Price_{t-1})$$

From this model, it is evident that the spot prices of the WTI index, New York Harbor Conventional Gasoline, and retail premium gasoline, all have significant effects on the retail price of regular gasoline. Yet, the differences in the signs for each coefficient highlight the differences on their individual impacts. For the WTI index, its increase in price directly leads to an increase in the retail price of gasoline. This relationship reinforces the conclusions of multiple previous literature as well as general understanding. When the price of the crude increases, inevitably the price of gasoline, which is refined from the crude, increases as well. This result additionally suggest that price increases in the raw material is transferred to the end consumer; although refiners and every other player down the gasoline supply chain will have to acquire their input at a higher price, the higher cost is ultimately transferred onto the end user of gasoline. It is interesting, however, that the price of the New York Harbor Conventional

Gasoline, a measure of the import price of gasoline, shares a negative relationship with the final retail price. This can be conceptualized by the fact that the major supply of gasoline in the United States are refined domestically, thus, when prices for gasoline retail are high, domestic producers have a much higher incentive to capture market volume to gain the marginally higher profits. As a result, foreign parties must lower their prices to meet the competition, leading to this observed negative relationship.

The negative relationship between the retail price of premium gasoline and regular gasoline highlight the difference between ordinary and luxury goods as defined in economic terms. When the price of premium gasoline, a luxury good, increases, consumers of this product are likely unable to substitute premium gasoline for regular gasoline as oftentimes their vehicles require the use of premium gasoline. Instead, sellers will be incentivized to capitalize on the generally higher demand for regular gasoline, thus driving up the price of regular gasoline. Since these different grades of motor gasoline come from the same sources with only minor differences in refining, refiners can easily change their outputs to meet market conditions while consumers of the premium gasoline are more inelastic in their demand.

In order to assess the strength of the model proposed, a partial autocorrelation correlogram was constructed for the residuals of the fitted values (Figure 3). The correlogram reveals that one residual is outside the confidence bands, suggesting that the second lag also accounts for the price of retail gasoline. This result indicates that the retail price of gasoline is not only affected by the price of the week immediate preceding but additional but the price two weeks in advance.

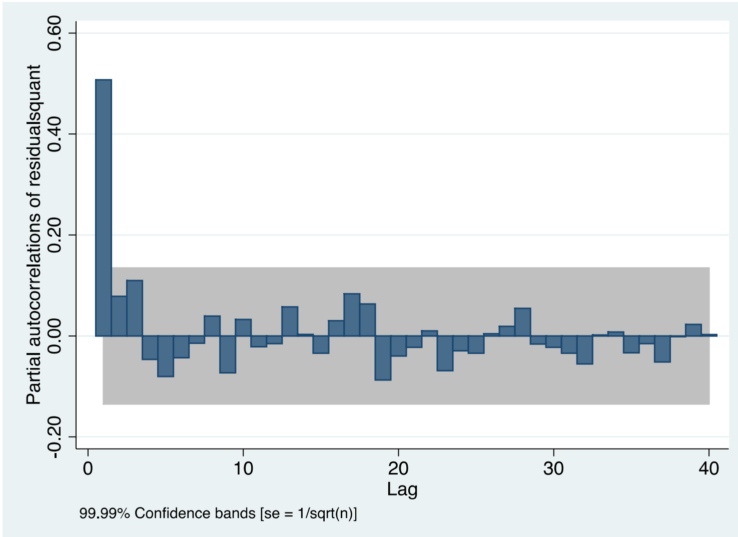


Figure 3: Partial Autocorrelation of residuals of model 1

5.4 Quantity

From the initial model on quantity, regression revealed that the variables stocks of crude oil, days of supply of crude oil, days of supply of total gasoline, import quantity of crude oil, import quantity of gasoline, export quantity of crude oil, export quantity of total petroleum products, and product supplied of finished motor gasoline are all not statistically significant at the $\alpha=0.05$ level. The lack of significance from these factors can be analyzed from two aspects. Firstly, those factors relating to the quantity and supply of finished gasoline do not significantly impact its pricing. This may appear as an anomaly at first but can be readily reconciled via a timing consideration. Retail gasoline is priced in anticipation of short-term future conditions, thus weight is placed on pricing from considerations of fluctuations and anticipated price changes in crude oil that will in the near future impact the supply of gasoline rather than considerations of its current availability. Secondly, those factors relating to exports are not significantly likely because the United States is a major net importer of these products and hence the effects of the minimal exports are reasonably trivial. Dropping the insignificant variables sequentially until only statistically significant variables remain, the resulting regression shows:

$$\log(Price) = -0.2796 + (0.0000119)DomesticProd + (.000000621)GasolineStock + (.00000422)TotalProductsSupplied + (1.004)\log(Price_{t-1})$$

This refined model strongly points to the significance of crude oil supply and gasoline stock. The positive relationship between domestic production of crude oil and the retail gasoline price is most evident; when domestic production increases, it is most likely due to demand as the United States traditionally imports the majority of its crude oil, as indicated by the data used for this investigation. Since domestically produced oil is generally more expensive than imported crude, naturally the retail price rises in concert with the observation between crude price and gasoline price of model 1. Extending this argument, when the stock of gasoline increases, the anticipated availability of gasoline decreases because it is being stockpiled instead. As a result, the price of retail gasoline increases.

In contrast, the total products supplied variable is a retrospective metric because it represents consumption of all petroleum products by measuring the disappearance of these products from primary sources such as refineries. Nonetheless, the positive relationship is expected because when consumption of petroleum products increases, it reflects higher demands for gasoline. For a given quantity of supply available since supply cannot adjust as quickly as demand in the short run, this will directly translate to higher retail prices for the consumer. As in model 1, a constructed correlogram again suggest the effect of a second lag of the dependent variable (Figure 4).

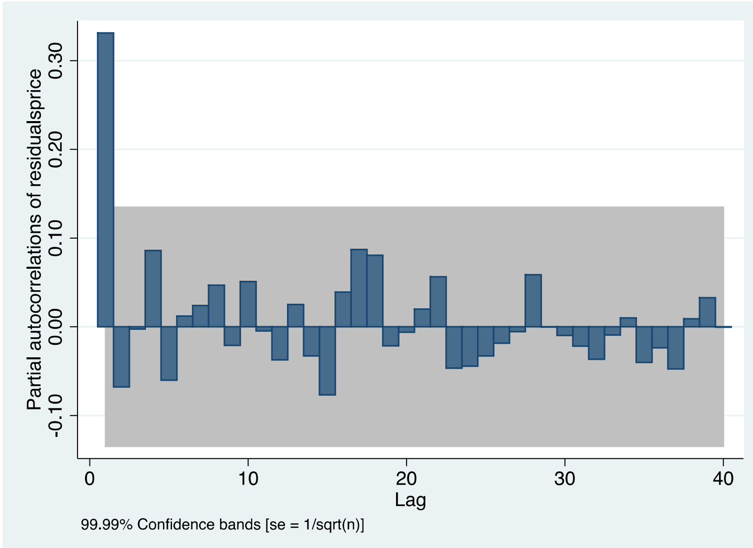


Figure 4: Partial Autocorrelation of residuals of model 2

5.5 Technology

In respect to technology, the third model reveals that the US refiner gross input of crude oil and other petroleum products, US operable crude oil distillation capacity, and US percent Utilization of refinery operable capacity are significant when regressed against the retail price of gasoline. The US Refiner net input of crude oil is, however, not significant. This insignificance likely stems from the technological capability of refineries to product motor gasoline from a variety of source beyond the traditional petroleum. When this variable is dropped, the resulting regression is given as:

$$\log(Price) = (-1.219) + (.0000789)GrossInputs + (-0.0000706)OperableCapacity + (-0.013566)PercentOperableUtilization + (.9953)\log(Price_{t-1})$$

In this case, the direct relationship between inputs into refineries and retail gasoline price is as expected. When the demand for motor gasoline is higher, refiners will choose to increase their output and in order to do so they must increase their amounts of input. Hence, increases in refinery input will directly correspond with increases in the retail price of gasoline. The inverse relationships between operable capacity as well as percent utilization and the retail price reflect not only the immediate benefits of technological increases but also an overall economic theme of advancement through technology. When operable capacity or percent utilization increases, the refineries are able to increase their output more efficiently and this efficiency is subsequently translated in the form of decreases to the end retail price. As in the previous models, the constructed partial autocorrelation correlogram point to the influence of an additional lag in the retail price of gasoline (Figure 5).

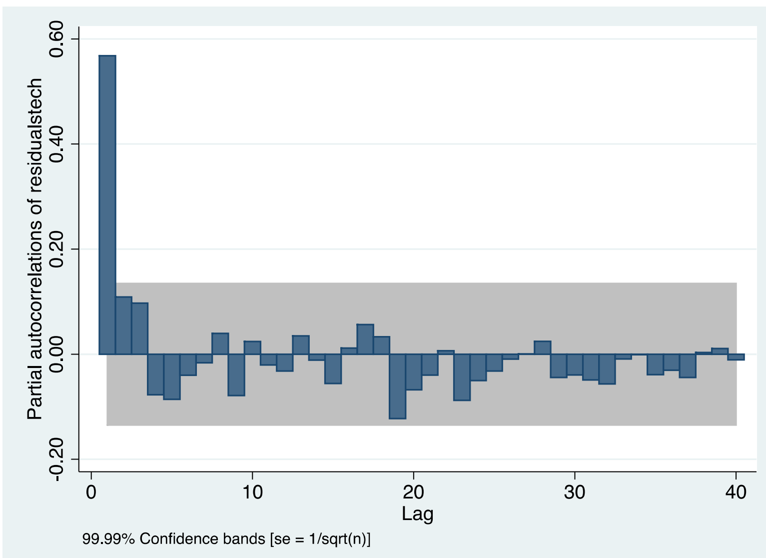


Figure 5: Partial Autocorrelation of residuals of model 3

In a greater context, the result is perhaps the most significant because it strategically directs future attention in the development of solutions to address the growing demand for sources of energy. While the world cannot in the short run abandon its dependence on crude oil as the predominant source of energy, society can look, and as this investigation concludes, find ways to better optimize this limited resource. By investing in infrastructure necessary for technological advancement, the rapidly growing demand for gasoline can be effectively addressed.

5.6 Limitations

It is important, however, to note the limitations of the models advanced in this investigation. Most critically, these models were designed to isolate the impact of direct inputs and substitutes on the price of regular motor gasoline in the United States. While this allows for an in-depth analysis of each determinant and the interplay between the factors, it does not take into account unexpected disturbances in the global macro economy. In this modern age of globalization, any turmoil in any part of the global network readily ripples throughout the world. Though these models accurately describe a balanced system that perpetually tends toward economic equilibrium in the long run, they are powerless in anticipating fluctuations in the short run.

Further, these models are built upon the principles of consumers behaving as rational agents as defined by economics. In other words, all participants in this system including producers, refiners, and consumers have all available information and are constantly making the most rational choices with this given set of information. However, as exhibited numerous times in history, deviation from this ration behavior in the form of irrational speculation is likely but unpredictable. When these speculation bubbles do occur, the very principles that guide free market economies are futile in explaining the behaviors of all agents involved. Consequently, given the unpredictability of these limitations, the models advanced in this investigation offer a comprehensive and robust approach to understanding the determinants of retail gasoline prices within a theoretical framework.

VI. Conclusion

This investigation found compelling evidence to support the hypotheses that spot prices of commodities, quantity/supply of petroleum products, and technology in refining have major impacts on the national retail price of gasoline. From the aspect of prices, it was determined that the WTI Index exhibited a positive relationship with the retail price of regular grade gasoline while the price of New York Harbor conventional gasoline and the retail price of premium gasoline negatively influenced the retail price of regular grade gasoline. Analyzing the significance of each relationship, it was determined that the differences in impact results from the nature of producing finished gasoline from raw crude and the transfer of rising costs of crude oil directly to the end use consumer. In the case of the negative relationship between regular gasoline and premium gasoline, this inverse behavior stems from the difference between ordinary and luxury goods that inhibit abilities to act as a substitute in the cases of the difference grades of gasoline. Except for the retail price of diesel fuel, the fact that all other variables were found to be significant highlight the dynamic interplay between spot prices of various petroleum products on the retail price of gasoline.

In the case of quantities, results of this investigation demonstrate the significance of domestic production of crude oil, domestic stock of gasoline, and total quantity of petroleum products supplied. Both increases in the domestic production of crude as well as the domestic stock of gasoline will cause the retail price of regular gasoline to rise. The ramifications for this finding counter the argument that domestic production is better economically than reliance on imports. Likely domestically produced oil has higher associated costs than imported oil and thus the higher cost is transferred to the consumer. Additionally, the negative consequence of stockpiling gasoline suggest while stockpiling may have long term benefits, its immediate effects lead to rises in retail gasoline price to the average consumer. Hence, in policy-making considerations, these results are significant because they raise the need to find a balance between developing domestic capabilities and relying on foreign imports.

Finally, with respect to technology in the form of refinery utilization, the significance of the US gross input of all petroleum products, US operable crude oil distillation capacity, and US percent Utilization of refinery operable capacity elucidate the impact of refining on the price of retail gasoline. The inverse relationship of retail gasoline price against operable capacity and percent utilization suggest that technology advancements hold the ultimate solution to addressing the ever-rapidly increasing demand for energy in the form of gasoline-related products. By investing in the infrastructure needed to enable refineries to operate more efficiently, retail prices can be decreased which has numerous additional implications on the greater macro economy.

Through a systematic analysis of the factors that impact the national retail price of regular gasoline in consideration of spot prices, quantities, and technology, this investigation provided a comprehensive examination of how each factor will positively or negatively impact the retail price. The models constructed in this study offer a complete approach to understanding how changes in individual factors will ripple through the complex gasoline supply chain. In terms of policy making, the work provides the basis for areas of target to strategically interact with the retail gasoline price, a critic driver of economic prosperity as it impacts all levels of production and consumption for a nation. Although limitations in the models exist when economic shocks and consumer irrationalities arise, the assumption of free market equilibrium in this approach will hold as a fundamental basis for economic decision making. Subsequent investigations into these extenuating circumstances, however, will readily build upon this investigation to establish a comprehensive model of determinations of the retail gasoline price.

VII. References

Al-Gudhea, Salim, Turalay Kenc, and Sel Dibooglu. 2007. "Do Retail Gasoline Prices Rise More Readily Than They Fall?: A Threshold Cointegration Approach." *Journal of Economics and Business* 59 (6) (November): 560–574. doi:10.1016/j.jeconbus.2006.10.002.

Archanskaïa, Elizaveta, Jérôme Creel, and Paul Hubert. 2012. "The Nature of Oil Shocks and the Global Economy." *Energy Policy* 42 (March): 509–520. doi:10.1016/j.enpol.2011.12.017.

Bacon, Robert W. 1991. "Rockets and Feathers: The Asymmetric Speed of Adjustment of UK Retail Gasoline Prices to Cost Changes." *Energy Economics* 13 (3) (July): 211–218. doi:10.1016/0140-9883(91)90022-R.

Barron, Jm, Ba Taylor, and Jr Umbeck. 2000. "A Theory of Quality-related Differences in Retail Margins: Why There Is a 'premium' on Premium Gasoline." *Economic Inquiry* 38 (4): 550–569. doi:10.1111/j.1465-7295.2000.tb00035.x.

Borenstein, Severin, A. Colin Cameron, and Richard Gilbert. 1997. "Do Gasoline Prices Respond Asymmetrically to Crude Oil Price Changes?" *The Quarterly Journal of Economics* 112 (1) (February 1): 305–339. doi:10.1162/003355397555118.

Borenstein, Severin, and Andrea Shepard. 1993. "Dynamic Pricing in Retail Gasoline Markets". Working Paper 4489. National Bureau of Economic Research. http://www.nber.org/papers/w4489.

———. 2002. "Sticky Prices, Inventories, and Market Power in Wholesale Gasoline Markets." *The RAND Journal of Economics* 33 (1) (April 1): 116–139. doi:10.2307/2696378.

Considine, Timothy J. 2001. "Markup Pricing in Petroleum Refining:: A Multiproduct Framework." *International Journal of Industrial Organization* 19 (10) (December): 1499–1526. doi:10.1016/S0167-7187(00)00055-2.

Considine, Timothy J., and Eunnyeong Heo. 2000. "Price and Inventory Dynamics in Petroleum Product Markets." *Energy Economics* 22 (5) (October): 527–548. doi:10.1016/S0140-9883(00)00056-6.

Duffy-Deno, Kevin T. 1996. "Retail Price Asymmetries in Local Gasoline Markets." *Energy Economics* 18 (1–2) (April): 81–92. doi:10.1016/0140-9883(95)00051-8.

Gary, James H., and Glenn E. Handwerk. 2001. *Petroleum Refining*. CRC Press.

Godby, Rob, Anastasia M. Lintner, Thanasis Stengos, and Bo Wandschneider. 2000. "Testing for Asymmetric Pricing in the Canadian Retail Gasoline Market." *Energy Economics* 22 (3) (June 1): 349–368. doi:10.1016/S0140-9883(99)00030-4.

Goto, Ujo, and C.R. McKenzie. 2002. "Price Collusion and Deregulation in the Japanese Retail Gasoline Market." *Mathematics and Computers in Simulation* 59 (1–3) (May 10): 187–195. doi:10.1016/S0378-4754(01)00407-4.

Hamilton, James D. 1983. "Oil and the Macroeconomy Since World War II." *Journal of Political Economy* 91 (2) (April 1): 228–248. doi:10.2307/1832055.

———. 1996. "This Is What Happened to the Oil Price-macroeconomy Relationship." *Journal of Monetary Economics* 38 (2) (October): 215–220. doi:10.1016/S0304-3932(96)01282-2.

Hastings, Justine S., and Richard J. Gilbert. 2005. "Market Power, Vertical Integration and the Wholesale Price of Gasoline*." *The Journal of Industrial Economics* 53 (4): 469–492. doi:10.1111/j.1467-6451.2005.00266.x.

Holmes, Mark J., Jesús Otero, and Theodore Panagiotidis. 2013. "On the Dynamics of Gasoline Market Integration in the United States: Evidence from a Pair-wise Approach." *Energy Economics* 36 (March): 503–510. doi:10.1016/j.eneco.2012.10.008.

Honarvar, Afshin. 2009. "Asymmetry in Retail Gasoline and Crude Oil Price Movements in the United States: An Application of Hidden Cointegration Technique." *Energy Economics* 31 (3) (May): 395–402. doi:10.1016/j.eneco.2009.01.010.

Hooker, Mark A. 1996. "What Happened to the Oil Price-macroeconomy Relationship?" *Journal of Monetary Economics* 38 (2) (October): 195–213. doi:10.1016/S0304-3932(96)01281-0.

Ichikawa, M., N. Nonaka, I. Takada, and S. Ishimori. 1992. "Estimation of the Octane Number of Automobile Gasoline by Fourier Transform Infrared Absorption Spectrometry." *Applied Spectroscopy* 46 (6) (June 1): 966–971.

Kaufmann, Robert K., Stephane Dees, and Micheal Mann. 2009. "Horizontal and Vertical Transmissions in the US Oil Supply Chain." *Energy Policy* 37 (2) (February): 644–650. doi:10.1016/j.enpol.2008.09.052.

Kaufmann, Robert K., and Cheryl Laskowski. 2005. "Causes for an Asymmetric Relation Between the Price of Crude Oil and Refined Petroleum Products." *Energy Policy* 33 (12) (August): 1587–1596. doi:10.1016/j.enpol.2004.01.013.

Mork, Knut Anton. 1989. "Oil and the Macroeconomy When Prices Go Up and Down: An Extension of Hamilton's Results." *Journal of Political Economy* 97 (3) (June 1): 740–744. doi:10.2307/1830464.

Pasadakis, Nikos, Vassilis Gaganis, and Charalambos Foteinopoulos. 2006. "Octane Number Prediction for Gasoline Blends." *Fuel Processing Technology* 87 (6) (June): 505–509. doi:10.1016/j.fuproc.2005.11.006.

Schmalensee, Richard, and Thomas M. Stoker. 1999. "Household Gasoline Demand in the United States." *Econometrica* 67 (3): 645–662. doi:10.1111/1468-0262.00041.

VIII. Appendix

Table 1: Summary of variables

Variable	***Abbreviation***	**Units**	**Description (Energy Information Administration)**
U.S. Regular All Formulations Retail Gasoline Prices	*PriceRegGas*	Dollars per Gallon	Price for Gasoline having an antiknock index (average of the research octane rating and the motor octane number) greater than or equal to 85 and less than 88. Note: Octane requirements may vary by altitude.
Cushing, OK WTI Spot Price	*PriceWTI*	Dollars per Barrel	A crude stream produced in Texas and southern Oklahoma which serves as a reference or "marker" for pricing a number of other crude streams and which is traded in the domestic spot market at Cushing, Oklahoma.
Europe Brent Spot Price	*PriceBrent*	Dollars per Barrel	A blended crude stream produced in the North Sea region which serves as a reference or "marker" for pricing a number of other crude streams.
New York Harbor Conventional Gasoline Regular Spot Price	*PriceNYCH*	Dollars per Gallon	The location specified in either spot or futures contracts for delivery of a product in New York Harbor.
U.S. Gulf Coast Conventional Gasoline Regular Spot Price	*PriceGulfC*	Dollars per Gallon	The location specified in either spot or futures contracts for delivery of a product in any port city along the coastline of Texas and Louisiana.
U.S. Midgrade All Formulations Retail Gasoline Prices	*PriceMidGas*	Dollars per Gallon	Price for Gasoline having an antiknock index, i.e., octane rating, greater than or equal to 88 and less than or equal to 90. Note: Octane requirements may vary by altitude.
U.S. Premium All Formulations Retail Gasoline Prices	*PricePremGas*	Dollars per Gallon	Price for Gasoline having an antiknock index, i.e., octane rating, greater than 90. Note: Octane requirements may vary by altitude.

U.S. No 2 Diesel Retail Prices	*PriceDiesel*	Dollars per Gallon	Price for a gasoil type distillate for use in high speed diesel engines generally operated under uniform speed and load conditions, with distillation temperatures between 540-640 degrees Fahrenheit at the 90-percent recovery point; and the kinematic viscosities between 1.9-4.1 centistokes at 100 degrees Fahrenheit as defined in ASTM specification D975-93. Includes Type R-R diesel fuel used for railroad locomotive engines, and Type T-T for diesel-engine trucks.
U.S. Field Production of Crude Oil	*QuantProdCrude*	Thousand Barrels Per Day	The volume of crude oil produced from oil reservoirs during given periods of time. The amount of such production for a given period is measured as volumes delivered from lease storage tanks to pipelines, trucks, or other media for transport to refineries or terminals with adjustments for (1) net differences between opening and closing lease inventories, and (2) basic sediment and water (BS&W).
U.S. Ending Stocks of Crude Oil	*QuantStockCrude*	Thousand Barrels	Inventories of Crude Oil stored for future use. Stocks are reported as of the last day of the period (e.g., week or month).
U.S. Ending Stocks of Total Gasoline	*QuantStockGas*	Thousand Barrels	Inventories of Gasoline stored for future use. Stocks are reported as of the last day of the period (e.g., week or month).
U.S. Days of Supply of Crude Oil	*QuantSupCrude*	Number of Days	A measure of the adequacy of inventories of Crude oil. It is calculated by taking the current stock level and dividing by product supplied averaged over the most recent four-week period. For crude oil, refinery inputs of crude oil are used as a proxy for demand
U.S. Days of Supply of Total Gasoline	*QuantSupGas*	Number of Days	A measure of the adequacy of inventories of Gasoline. It is calculated by taking the current stock level and dividing by product supplied (used as an estimate of demand) averaged over the most recent four-week period.
U.S. Imports of Crude Oil	*QuantImpCrude*	Thousand Barrels Per Day	Receipts of crude oil into the 50 States and the District of Columbia from foreign countries, Puerto Rico, the Virgin Islands, and other U.S. possessions and territories.

U.S. Imports of Total Gasoline	*QuantImpGas*	Thousand Barrels Per Day	Receipts of total Gasoline into the 50 States and the District of Columbia from foreign countries, Puerto Rico, the Virgin Islands, and other U.S. possessions and territories.
U.S. Exports of Crude Oil	*QuantExpCrude*	Thousand Barrels Per Day	Shipments of crude oil from the 50 States and the District of Columbia to foreign countries, Puerto Rico, the Virgin Islands, and other U.S. possessions and territories.
U.S. Exports of Total Petroleum Products	*QuantExpGas*	Thousand Barrels Per Day	Shipments of all petroleum products from the 50 States and the District of Columbia to foreign countries, Puerto Rico, the Virgin Islands, and other U.S. possessions and territories.
U.S. Product Supplied of Petroleum Products	*QuantTotPetro*	Thousand Barrels Per Day	Approximately represents consumption of petroleum products because it measures the disappearance of these products from primary sources, i.e., refineries, natural gas processing plants, blending plants, pipelines, and bulk terminals.
U.S. Product Supplied of Finished Motor Gasoline	*QuantTotGas*	Thousand Barrels Per Day	Approximately represents consumption of Finished Motor Gasoline because it measures the disappearance of these products from primary sources
U.S. Refiner Net Input of Crude Oil	*TechInputCrude*	Thousand Barrels Per Day	The total crude oil put into processing units at refineries.
U.S. Gross Inputs into Refineries	*TechInputGross*	Thousand Barrels Per Day	The crude oil, unfinished oils, and natural gas plant liquids put into atmospheric crude oil distillation units.
U. S. Operable Crude Oil Distillation Capacity	*TechCapacity*	Thousand Barrels Per Day	The amount of capacity that, at the beginning of the period, is in operation; not in operation and not under active repair, but capable of being placed in operation within 30 days; or not in operation but under active repair that can be completed within 90 days. Operable capacity is the sum of the operating and idle capacity and is measured in barrels per calendar day or barrels per stream day.
U.S. Percent Utilization of Refinery Operable Capacity	*TechPercentUtil*	Percent	Represents the utilization of all crude oil distillation units. The rate is calculated by dividing gross inputs to these units by the operating/operable refining capacity of the unit.

Table 2: Summary of regression results

Variable	Abbreviation	Coefficient	Retail Price Relationship
Cushing, OK WTI Spot Price	PriceWTI	.0005297	Positive
New York Harbor Conventional Gasoline Regular Spot Price	PriceNYCH	-0.0852	Negative
U.S. Premium All Formulations Retail Gasoline Prices	PricePremGas	-.00473	Negative
U.S. No 2 Diesel Retail Prices	PriceDiesel	Not Statistically Significant	Not Statistically Significant
U.S. Field Production of Crude Oil	QuantProdCrude	.0000119	Positive
U.S. Ending Stocks of Crude Oil	QuantStockCrude	Not Statistically Significant	Not Statistically Significant
U.S. Ending Stocks of Total Gasoline	QuantStockGas	.000000621	Positive
U.S. Days of Supply of Crude Oil	QuantSupCrude	Not Statistically Significant	Not Statistically Significant
U.S. Days of Supply of Total Gasoline	QuantSupGas	Not Statistically Significant	Not Statistically Significant
U.S. Imports of Crude Oil	QuantImpCrude	Not Statistically Significant	Not Statistically Significant
U.S. Imports of Total Gasoline	QuantImpGas	Not Statistically Significant	Not Statistically Significant
U.S. Exports of Crude Oil	QuantExpCrude	Not Statistically Significant	Not Statistically Significant
U.S. Exports of Total Petroleum Products	QuantExpGas	Not Statistically Significant	Not Statistically Significant
U.S. Product Supplied of Petroleum Products	QuantTotPetro	.00000422	Positive
U.S. Product Supplied of Finished Motor Gasoline	QuantTotGas	Not Statistically Significant	Not Statistically Significant
U.S. Refiner Net Input of Crude Oil	TechInputCrude	Not Statistically Significant	Not Statistically Significant
U.S. Gross Inputs into Refineries	TechInputGross	.0000789	Positive
U. S. Operable Crude Oil Distillation Capacity	TechCapacity	-.0000706	Negative
U.S. Percent Utilization of Refinery Operable Capacity	TechPercentUtil	-0.013566	Negative

Table 3: Summary of seasonality regression

Variable	Coefficient	Standard Error	t-statistic	P>|t|
d1	0.0885484	0.1379586	0.64	0.521
d2	0.0836059	0.1379586	0.61	0.545
d3	0.0936423	0.1379586	0.68	0.497
d4	0	(omitted)		
d5	0.0170996	0.1379586	0.12	0.901
d6	0.0224897	0.1379586	0.16	0.871
d7	0.0381451	0.1379586	0.28	0.782
d8	0.0558533	0.1379586	0.4	0.686
d9	0.06052	0.1379586	0.44	0.661
d10	0.0714869	0.1379586	0.52	0.604
d11	0.0774871	0.1379586	0.56	0.575
d12	0.0983454	0.1379586	0.71	0.476
d13	0.1008617	0.1379586	0.73	0.465
d14	0.1057519	0.1379586	0.77	0.444
d15	0.113073	0.1379586	0.82	0.413
d16	0.120797	0.1379586	0.88	0.382
d17	0.1391555	0.1379586	1.01	0.313
d18	0.1534299	0.1379586	1.11	0.266
d19	0.1468873	0.1379586	1.06	0.287
d20	0.1439837	0.1379586	1.04	0.297
d21	0.1485718	0.1379586	1.08	0.282
d22	0.1548519	0.1379586	1.12	0.262
d23	0.1411658	0.1379586	1.02	0.307
d24	0.1432542	0.1379586	1.04	0.299
d25	0.1403656	0.1379586	1.02	0.309
d26	0.1482699	0.1379586	1.07	0.283
d27	0.1479793	0.1379586	1.07	0.284
d28	0.1335895	0.1379586	0.97	0.333
d29	0.1498444	0.1379586	1.09	0.278
d30	0.1532464	0.1379586	1.11	0.267
d31	0.1555512	0.1379586	1.13	0.26
d32	0.156946	0.1379586	1.14	0.256
d33	0.1522033	0.1379586	1.1	0.27
d34	0.1633554	0.1379586	1.18	0.237
d35	0.1498694	0.1379586	1.09	0.278
d36	0.1338476	0.1379586	0.97	0.332
d37	0.1503046	0.1379586	1.09	0.276
d38	0.1403637	0.1379586	1.02	0.309

d39	0.1351498	0.1379586	0.98	0.328
d40	0.1311481	0.1379586	0.95	0.342
d41	0.112915	0.1379586	0.82	0.413
d42	0.1048847	0.1379586	0.76	0.447
d43	0.0942136	0.1379586	0.68	0.495
d44	0.0960911	0.1379586	0.7	0.486
d45	0.0821021	0.1379586	0.6	0.552
d46	0.0727061	0.1379586	0.53	0.598
d47	0.0743888	0.1379586	0.54	0.59
d48	0.073277	0.1379586	0.53	0.595
d49	0.082489	0.1379586	0.6	0.55
d50	0.0758305	0.1379586	0.55	0.583
d51	0.0783961	0.1379586	0.57	0.57
d52	0.091177	0.1379586	0.66	0.509
d53	0	(omitted)		
_cons	0.4287427	0.0975514	4.4	0

Table 4: Regression 1a, Spot Prices

Variable	Coefficient	Standard Error	t-statistic	P>|t|
L1.	0.9600696	0.0082433	116.47	0
pricewti	0.0007315	0.0001648	4.44	0
pricenych	-0.0870073	0.0073253	-11.88	0
pricepremgas	-0.0339783	0.0052692	-6.45	0
pricediesel	-0.0094828	0.0052014	-1.82	0.069
_cons	-0.0379112	0.0059191	-6.4	0

Table 5: Regression 1b, Spot Prices (insignificant variables dropped)

Variable	Coefficient	Standard Error	t-statistic	P>|t|
L1.	0.9615676	0.0082137	117.07	0
pricewti	0.0005297	0.0001222	4.33	0
pricenych	-0.085152	0.0072645	-11.72	0
pricepremgas	-0.0382245	0.0047331	-8.08	0
_cons	-0.0385542	0.0059169	-6.52	0

Table 6: Regression 2a, Quantity

Variable	**Coefficient**	**Standard Error**	**t-statistic**	**P>|t|**
L1.	1.003842	0.0051221	195.98	0
quantprodcrude	0.0000124	2.88E-06	4.31	0
quantstockcrude	3.19E-08	3.07E-08	1.04	0.3
quantstockgas	7.40E-07	2.00E-07	3.69	0
quantsupcrude	0.0000767	0.0007519	0.1	0.919
quantsupgas	- 0.0012416	0.0015224	-0.82	0.415
quantimpcrude	1.30E-07	1.14E-06	0.11	0.909
quantimpgas	-8.44E-06	4.16E-06	-2.03	0.043
quantexpcrude	- 0.0000297	0.0000233	-1.28	0.202
quantexpgas	-5.68E-06	4.12E-06	-1.38	0.169
quanttotpetro	4.36E-06	1.18E-06	3.71	0
quanttotgas	-2.64E-06	3.58E-06	-0.74	0.46
_cons	-0.276003	0.040897	-6.75	0

Table 7: Regression 2b, Quantity (insignificant variables dropped)

Variable	**Coefficient**	**Standard Error**	**t-statistic**	**P>|t|**
L1.	1.003683	0.0033282	301.57	0
quantprodcrude	0.0000119	2.52E-06	4.72	0
quantstockgas	6.21E-07	7.10E-08	8.75	0
quanttotpetro	4.22E-06	8.20E-07	5.15	0
_cons	- 0.2795932	0.029755	-9.4	0

Table 8: Regression 3a, Technology

Variable	Coefficient	Standard Error	t-statistic	P>|t|
L1.	0.9949684	0.0040844	243.6	0
techinputcrude	-2.46E-06	8.31E-06	-0.3	0.767
techinputgross	0.0000823	0.0000257	3.2	0.001
techcapacity	-0.0000714	0.0000216	-3.31	0.001
techpercentutil	-0.0137064	0.0039587	-3.46	0.001
_cons	1.232795	0.36725	3.36	0.001

Table 9: Regression 3b, Technology (insignificant variables dropped)

Variable	Coefficient	Standard Error	t-statistic	P>|t|
L1.	0.995312	0.0039139	254.3	0
techinputgross	0.0000789	0.0000231	3.41	0.001
techcapacity	-0.0000706	0.0000214	-3.3	0.001
techpercentutil	-0.013566	0.003928	-3.45	0.001
_cons	1.219479	0.3642844	3.35	0.001

Table 10: Regression 4, Time Trend Analysis

Variable	Coefficient	Standard Error	t-statistic	P>|t|
time	1.27E-05	6.87E-06	1.85	0.065
L1.	0.991932	0.004293	231.06	0
_cons	-0.02287	0.013377	-1.71	0.088